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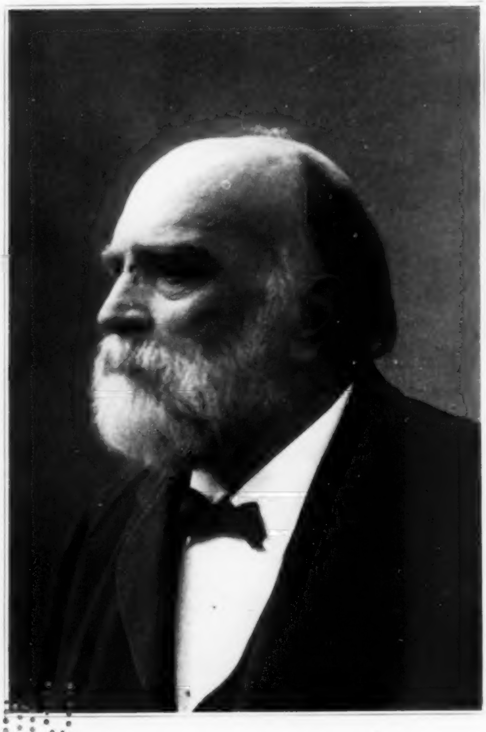

NILS CHRISTOFER DUNÉR

THE
ASTROPHYSICAL JOURNAL
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VOLUME XLI — MARCH 1915 — NUMBER 2

NILS CHRISTOFER DUNÉR

By ANDERS ÅNGSTRÖM

By the death of Nils Christofer Dunér, late professor at the University of Upsala, who died on November 10, 1914, at the age of seventy-five years, the science of astronomy lost one of its most remarkable followers.

Dunér's career shows what important scientific work can be accomplished even with the aid of comparatively slight resources, provided that there is no lack of the necessary personal qualifications—unconquerable energy, capacity for scientific reasoning, and an ardent interest in the problem in hand.

The work of pioneers in the study of astronomy has often been carried on by the aid of the slender resources of small observatories. As an example of this may be adduced the career of Sir William Huggins, which was sketched not long ago in the pages of this *Journal;* another example is that of Dunér, whose work, especially in connection with double stars and the rotation of the sun, will always be looked upon as laying the foundations for future study in special departments of his science.

Dunér was born on May 21, 1839, at Billeberga, in the Swedish province of Scania, where his father was vicar. After having matriculated at Lund, he became extra assistant at the observatory there as early as 1858, and in 1864 he was appointed observer,

having taken his Doctor's degree earlier in the same year. This position provided Dunér with opportunities for developing considerable activity. After the newly established observatory at Lund had been provided with a larger refractor in 1864, Dunér began a systematic investigation of the double stars. The results of these comprehensive labors are brought together in his *Mésures micrométriques d'etoiles doubles, faites à l'Observatoire de Lund, suivies de notes sur leurs mouvements relatifs*, published in 1876. In this book Dunér discusses at length the results of earlier investigations, besides advancing a large number of new suggestions and describing many new investigations. The work is one of our principal authorities on double stars.

Probably it is in the choice of the problem to be attacked that scientific genius chiefly betrays itself. Methods grow antiquated and are improved upon, scientific results are modified and corrected, and, seen in the light of new discoveries, they get a new meaning. But as the most important task there always remains the keen sensing out of the real problems, on the solving of which science is built up, and which, vigorously debated and variously interpreted, incite succeeding generations to further investigations.

It is to this department that the following two great works of Dunér belong. These were *Sur les Etoiles à Spectre de la troisième classe*, published in 1884, and *Recherches sur la rotation du soleil*, published in 1891, after Dunér had been called to fill the chair of astronomy at Upsala. The latter of these two works proved to be his greatest triumph and suggested new problems. The former of them presents a penetrating investigation on the subject of the spectra of the red and reddish-colored stars (Vogel's third class). About twenty years after the appearance of this volume, Hale and Ellerman expressed themselves about it as follows: "In spite of the small aperture of his telescope, the low dispersion which was necessarily employed and the serious difficulties that are almost invariably encountered in visual observations of faint spectra, Dunér's results are of the highest value and have been confirmed in almost every particular by our photographs." In this work Dunér also presents an interesting and notable discussion regarding the development of the stars of the fourth order.

He shows that stars of type IV have a distinct tendency to collect in the Milky Way.

The work, however, upon which Dunér's reputation chiefly rests is his celebrated treatise on the rotation of the sun. Carrington (1853–1861), through a study of the movements of the sun-spots, had made the remarkable discovery that the rotation period of the sun declines from the equator to the poles; but on account of the limited frequency of the occurrence of the sun-spots, this observation could be effected only for the portion of the sun's surface lying between the equator and 40° of latitude. Dunér attacked this problem in a new and brilliant way, employing Doppler's principle for determining the rotations in different parts of the sun's disk. By measuring the shifts of the lines λλ 6302.709 Fe and 6302.975 A(O) on the periphery relatively to the center, he corroborated, as we know, Carrington's observations and found that the rotation period at the equator was 25.5 days, while at 15° from the poles it was 38.5 days. Several years later Dunér resumed his investigations, this time with the collaboration of one of his pupils, the present director of the Upsala Observatory, Professor Östen Bergstrand, and the results gained confirmed, on the whole, those obtained in the previous investigations.

As is well known, Dunér's method of determining the sun's rotation by means of an application of Doppler's principle has since been more widely used. By the application of this principle, Hale and his associates, at Mount Wilson, and Deslandres, at Meudon, have arrived at a clear conception of the movement in different parts of the solar atmosphere.

With regard to Dunér's other work, it may be mentioned that he conducted painstaking and successful investigations with regard to the variable stars Y Cygni and Z Herculis, belonging to the Algol type. He showed that the path of the one component around the other is markedly eccentric, and that the line of apsides rotates around the common center of gravity.

Dunér's astronomical work proves him to have been a brilliant and original scientist. He was a painstaking investigator of uncommon ability. Neither his talents nor his inclinations lay in the direction of theoretical speculations or comprehensive hypotheses,

and he accepted Newton's well-known *hypotheses non fingo*. For one who has accustomed himself to advance step by step, by means of painstaking scientific work, toward sure conclusions, the stride of theoretical speculation often seems to result in advances of slight worth. Dunér was bold in attacking important and exacting problems, but careful in the matter of drawing conclusions.

It is not only as an investigator that Dunér was active; he also rendered great service as a scientific organizer. Even as far back as 1861 and 1864, he took part in the Swedish expedition to Spitzbergen, where, in company with A. E. Nordenskiöld, he made preliminary investigations with the object of investigating the possibility of measuring a degree in those regions. Thanks to co-operation between Sweden and Russia, the measurement was effected, and Dunér took an active part in carrying on the work.

Further, he was one of the founders of the *Astronomische Gesellschaft;* he took an active part in astronomical meetings and the astro-photographic congresses, and he developed fruitful activity in the preparation of the international photographic map of the heavens. He was, besides, one of the editors of the *Astrophysical Journal*.

Among all the scientific distinctions that fell to the share of Dunér we may only mention that in 1887 he was awarded the Lalande Prize by the French Institute, and in 1892 the Rumford Gold Medal by the Royal Society in London.

Scientific investigation was, for Dunér, one of the necessities of life, and he devoted himself to his task with energy and zest. At the same time his work was stamped by that boyish curiosity which is such a remarkable trait in every great man of science. The writer remembers that the wall of his study was adorned by a French india-ink drawing representing an astronomer who, with every indication of enthusiasm, is telling a friend—who evidently does not share his joy—that he has discovered that, within a short time, the earth will collide with a comet. This astronomer might very well have been Dunér himself. He thought, with Poincaré, that the pursuit of truth is perhaps the most important object of our activities.

Dunér's interests were uncommonly all-embracing. He expressed himself with ease in most European languages, and as a boy he had taught himself Spanish, in order to be able to read *Don Quixote* in the original. After he had resigned his professorial chair in 1909, he occupied his leisure hours by translating Dante's *Divina Comedia*. His interest for comparative philology was so great that he was once known to have said that he would possibly have been a better linguist than astronomer. This we doubt, not because of his lack of ability in the study of languages, but because of his rare qualities as a scientist: his clear mind for inductive reasoning, and his great experimental genius.

UPSALA
January 1915

THE VARIATION WITH TEMPERATURE OF THE ELECTRIC FURNACE SPECTRA OF VANADIUM AND CHROMIUM[1]

By ARTHUR S. KING

The electric furnace spectra to be treated in this paper cover the range of wave-length from λ 3150 to λ 6850 for vanadium, and from λ 3550 to λ 7000 for chromium. The method of classification as to the initial temperature at which a spectrum line appears and its rate of increase in intensity as the temperature rises is similar to that used in previous studies of the spectra of iron[2] and titanium.[3]

APPARATUS AND METHODS

The tube resistance furnace was operated *in vacuo* according to the method described in previous papers. A distinct gain in the photography of the spectrum was obtained by the use of the vertical concave-grating spectrograph[4] recently mounted in the Pasadena laboratory. The spectra under examination being very rich in lines, especially in the region of shorter wave-length, the second order of this 15-foot grating was used to advantage in the crowded region extending to about λ 4500. The scale is approximately 1 mm = 1.85 A, and a range of about 850 A is obtained on a single plate. The first order gives a spectrum of high intensity and its scale was sufficient for the region toward the red. Seed "Gilt-Edge 27" plates were used throughout the spectrum, being bathed with the Wallace solution of pinacyanol, pinaverdol, and homocol for the region from λ 5000 into the red. A number of photographs of the whole spectrum were also made with a 1-meter concave grating to record the lines most persistent at low temperature and to observe the general changes in intensity with wave-length for the several furnace temperatures and for the arc.

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 94.

[2] *Mt. Wilson Contr.*, No. 66; *Astrophysical Journal*, **37**, 239, 1913.

[3] *Mt. Wilson Contr.*, No. 76; *Astrophysical Journal*, **39**, 139, 1914.

[4] *Mt. Wilson Contr.*, No. 84; *Astrophysical Journal*, **40**, 205, 1914.

The three temperatures on which the classification for both vanadium and chromium is based were given by a Wanner pyrometer as 2000–2150° C. for the low, 2300–2350° C. for the medium, and 2500–2600° C. for the high temperature plates. With vanadium, 2000° C. appears to be about the lower limit for the appearance of a spectrum, though the lines produced at this temperature are fairly numerous. The case is different for chromium, the melting-point of which is considerably lower. Temperatures between 1700° and 1800° C. sufficed to give a number of the most persistent lines in this spectrum, which are listed in a separate table. The somewhat richer spectrum given at 2000°, however, was better suited to show the development of the lines from this into the medium and high temperatures.

The metals used in the furnace were metallic vanadium and crystalline chromium, both supplied by Eimer and Amend. These substances were of fair purity and as the furnace tubes used were of regraphitized Acheson graphite, the spectra obtained showed but few impurity lines of sufficient strength to be disturbing.

EXPLANATION OF THE TABLES

Wave-lengths.—The wave-lengths in the first column of Tables I and II are those given by Exner and Haschek[1] for the arc spectrum, supplemented occasionally by those of Hasselberg,[2] indicated by *H*, usually in cases where close doublets were not resolved by Exner and Haschek. Several chromium lines which are very wide in the arc in air were sometimes found to be resolved into as many as three sharp lines by the vacuum furnace. A vacuum arc furnished by special fittings inside the furnace chamber also gave sharp lines in these cases, which were measured from neighboring chromium lines and the wave-lengths entered in the table.

An asterisk after the wave-length denotes that an explanatory remark for the given line is to be found at the end of the table.

Arc intensities.—These were estimated by the writer from arc spectra taken on the same plates as the furnace spectra, the vanadium arc being given by the metal in the carbon arc, while that

[1] *Spektren der Elemente bei normalem Druck*, Leipzig, 1911.

[2] *Kgl. svenska vet. akad. handl.*, **26**, 1894; **32**, 1899; see also Kayser, *Handbuch der Spectroscopie*, **5**, 337; **6**, 750.

of chromium was formed between lumps of the metal. The arc photograph used was in each case of moderate exposure, the spectrum in general being comparable in intensity with that of the high-temperature furnace. Numerous nebulous lines, especially in the chromium table, are indicated by *n* after the intensity value. A vacuum source, either arc or furnace, serves in general to sharpen such lines. The letters *R* and *r*, both for arc and for furnace lines, indicate complete and partial self-reversal, respectively.

Furnace intensities.—In estimating the intensities of furnace lines an effort was made to obtain correct relative intensities for the lines for each temperature, a line distinctly outlined on the plate being given the intensity "1," a fainter appearance being indicated as "trace" (*tr*). The appearance of a line is usually much altered as the temperature rises, but the relative change of different lines with increase of temperature is shown in the tables.

Classification.—The method of assigning lines to classes is the same as that used for the titanium spectrum and is but slightly modified from the system used for iron. Class I lines are relatively strong at low temperatures and strengthen slowly at higher temperatures. Many of them are given the same intensity for the three temperatures and for the arc. Class II lines appear at low temperature but strengthen more rapidly than those of Class I as the tube becomes hotter. The basis of division between these classes, while sometimes rather arbitrary, is usually well defined. The lines of Class III are absent or faint at low temperature, appear at medium temperature, and are usually considerably stronger at high temperature. Class IV lines appear only at the highest furnace temperature, sometimes faintly at medium; while those of Class V are usually absent in the furnace or, if present, are faint compared to the arc intensity. For vanadium, as for titanium, this class is limited almost entirely to the enhanced lines, which are indicated by *V E*. Faint lines given in the arc tables are not entered in this list unless they appear also in the furnace.

The use of *A* after the class number indicates that the line in question is relatively weak in the arc, being usually not more than half as strong as in the high-temperature furnace. The significance of lines of this character will be considered in the discussion.

TABLE I

Temperature Classification of Vanadium Lines

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
3164.96	5				V E	3241.30	4	4	2		III
3168.25	6				V E	3242.14	1	2	tr		III A
3170.47	2	2	2	1	II	3243.42	3	4	2		III
3183.53	30r	50R	30R	10r	II	3246.96	1	1			IV
3184.11	60R	100R	60R	20r	II	3248.81	3	3	2		III
3185.51	40R	80R	40R	15r	II	3249.69	10	8	6	5	II
3187.81	10	tr			V E	3250.12	2	2	1		III
3188.21	3	1			IV	3250.90	4				V E
3188.60	10	tr			V E	3252.01	4				V E
3189.16	1	1			IV	3253.00	1	1			IV
3190.80	15	1			V E	3254.91	10	5	3	1	II
3194.07	6	5	4	2	II	3255.79	9	5	4	1	III
3194.53	2	1			IV	3256.60	1	1			IV
3194.70	1	tr			IV	3257.00	1	tr			IV
3195.05	1	tr			IV	3259.67	5	4	3	tr	III
3198.13	20	30R	15r	6	II	3261.21	6	3	1		III
3199.97	6	3	2		III	3262.20	5	4	1		III
3201.35	2	4	2	tr	III A	3263.39	15	15r	8	5	II
3202.51	25	35R	18r	6	II	3266.02	5	2	tr		IV
3204.30	3	3	3	2	I	3266.20	4	3	2		III
3205.36	5	2	1		III	3267.83	20	1			V E
3205.69	15	6	4	3	II	3271.25	20	1			V E
3207.01	1	1			IV	3271.53	3	2	2		III
3207.51	20	30R	15r	5	II	3271.80	12	12r	7	4	II
3208.46	6				V E	3272.30	1	1	tr		III
3210.22	4	3	1		III	3273.16	7	4	3	1	II
3210.54	2	2	tr		IV	3276.23	20	1			V E
3211.68	1	1	tr		III	3278.02	5	10r	6	3	II A
3212.57	15	6	4	3	II	3279.97	6				V E
3214.04	2	2	1		III	3281.25	3				V E
3214.86	6				V E	3282.67	5				V E
3215.47	4	4	3	2	II	3283.46	15	15r	8	6	II
3217.20*	10	7?	5?	2?	II ?	3284.47	6	5	4	1	III
3218.45	1	3	2	tr	III A	3288.55	2	2	1		III
3218.98	5	3	2	tr	III	3289.51	6				V E
3225.76	1	4	1		III A	3291.81	4	4	4	3	I
3226.23	4	4	3	2	II	3295.56	1	1			IV
3227.21	3	3	1		III	3298.28	15	15r	10	8	II
3227.53	4	2	tr		IV	3298.85	6				V E
3228.31	3	3	1		III	3299.20	3	3	2		III
3229.72	4	2	tr		IV	3299.32	1	1			IV
3230.76	6	6	5	3	II	3300.08	2	2	1		III
3232.07	2				V E	3308.36	3	4	4	1	III
3233.33	6	4	3	tr	III	3309.03	1	1			IV
3233.68	2				V E	3309.30	8	4	3	1	II
3233.93	3				V E	3313.14	2	2	1		III
3234.86	2	3	2	tr	III	3314.11	3	2	tr		IV
3238.00	8				V E	3316.01	1	1			IV
3239.06	1	1			IV	3319.14	4	3	1		III

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.	
3319.91	1	1	.....	.....	IV
3320.30	3	3	2	.....	III
3321.80	5	3	1	.....	III
3324.37	1	1	.....	.....	IV
3324.55	3	2	1	.....	III
3326.52	1	1	.....	.....	IV
3327.30	tr	tr	.....	.....	IV
3328.12	2	1	.....	.....	IV
3328.54	2	1	.....	.....	IV
3330.01	12	8	6	3	II
3332.60	tr	tr	.....	.....	IV
3333.70	2	2	1	.....	III
3334.28	tr	tr	.....	.....	IV
3336.35	1	1	.....	.....	IV
3336.49	2	1	.....	.....	IV
3336.93	2	1	.....	.....	IV
3340.31	1	1	.....	.....	IV
3342.42	2	1	.....	.....	IV
3345.15	tr	tr	.....	.....	IV
3356.50	10	7	5	2	II
3362.2	1	tr	.....	.....	IV
3363.70	4	5	3	tr	III
3365.71	10	7	5	3	II
3367.02	4	4	3	1	II
3367.18	1	1	.....	.....	IV
3369.1	1	1	.....	.....	IV
3371.27	3	1	.....	.....	IV
3372.94	tr	1	.....	.....	IV A
3374.17	3	4	2	.....	III
3376.20	8	6	5	2	II
3377.51	10	8	6	3	II
3377.75	15	10	8	6	II
3379.49	2	1	.....	.....	IV
3384.71	5	5	4	1	III
3387.50	2	1	.....	.....	IV
3389.64	tr	tr	.....	.....	IV
3390.51	2	2	1	.....	III
3390.91	6	5	4	1	III
3394.90	2	1	.....	.....	IV
3395.64	3	3	1	.....	III
3396.65	3	2	tr	.....	IV
3397.70	6	5	4	1	III
3397.97	4	5	4	1	III
3398.39	1	1	.....	.....	IV
3400.55	12	8	6	4	II
3401.49	2	2	1	.....	III
3402.73	9	7	5	3	II
3403.51	5	4	1	.....	III
3405.09	2	2	tr	.....	IV
3405.30	6	5	4	2	II
3406.96	6	6	4	1	III
3408.13	3	3	2	tr	III
3408.60	1	4	3	1	II A
3409.21	4	3	1	.....	III
3411.10	1	1	.....	.....	IV
3413.90	1	1	.....	.....	IV
3414.32	5	5	4	2	II
3416.65	2	5	4	2	II A
3417.17	5	5	4	2	II
3418.63	5	5	4	2	II
3424.00	3	3	1	.....	III
3425.20	6	4	3	1	II
3425.37	1	tr	.....	.....	IV
3426.06	1	5	4	2	II A
3426.87	1	2	1	.....	III A
3427.60	1	1	.....	.....	IV
3432.19	1	1	.....	.....	IV
3437.91	1	1	.....	.....	IV
3439.13	tr	tr	.....	.....	IV
3442.14	2	1	.....	.....	IV
3442.45	2	2	1	.....	III
3443.69	1	1	.....	.....	IV
3445.00	1	1	.....	.....	IV
3445.93	2	2	tr	.....	IV
3447.23	tr	tr	.....	.....	IV
3453.12	tr	tr	.....	.....	IV
3453.65	1	1	.....	.....	IV
3455.02	3	2	tr	.....	IV
3455.36	1	1	.....	.....	IV
3455.70	1	1	.....	.....	IV
3455.95	tr	tr	.....	.....	IV
3457.04	4	4	2	.....	III
3457.23	3	.....	.....	.....	V E
3460.23	1	3	1	.....	III A
3463.53	2	6	4	3	II A
3465.48	tr	tr	.....	.....	IV
3482.31	1	1	.....	.....	IV
3486.05	6	2	1	.....	III
3487.14	2	2	1	.....	III
3489.58	4	4	2	.....	III
3490.40	1	1	.....	.....	IV
3491.54	tr	tr	.....	.....	IV
3493.32	4	.....	.....	.....	V E
3496.40	1	1	.....	.....	IV
3497.09	3	3	1	.....	III
3498.34	3	3	1	.....	III
3500.47	1	1	.....	.....	IV
3500.96	3	2	2	.....	III
3501.64	4	4	3	tr	III
3503.31	1	1	tr	.....	III
3504.60	12	.....	.....	.....	V E
3505.39	1	1	.....	.....	IV

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
3505.84....	6	6	4	1	III	3580.97....	3	3	1	.....	III
3506.99....	3	3	1	.....	III	3582.97....	3	3	1	.....	III
3516.35....	1	1	.....	.....	IV	3583.85*...	8	12	8	3	II
3517.44....	12	tr	.....	.....	V E	3586.34....	2	.....	.....	.....	V
3518.27....	tr	tr	.....	.....	IV	3589.89....	15	tr	.....	.....	V E
3519.31....	3	3	1	.....	III	3591.23....	1	1	tr	.....	III
3520.16....	5	.....	.....	.....	V E	3592.16....	15	tr	.....	.....	V E
3522.00....	2	.....	.....	.....	V E	3592.32....	1	4	3	1	II A
3522.73....	3	3	1	.....	III	3592.70....	3	2	1	.....	III
3524.86....	6	.....	.....	.....	V E	3593.49....	12	.....	.....	.....	V E
3525.90....	1	1	tr	.....	III	3595.75....	1	1	tr	.....	III
3528.35....	1	1	tr	.....	III	3598.26....	1	1	tr	.....	III
3529.89....	10	8	6	4	II	3600.16....	5	5	3	1	II
3530.91....	10	.....	.....	.....	V E	3604.24....	1	tr	.....	.....	IV
3533.87*...	{10	6	6	5	I	3605.77....	3	1	tr	.....	III
	6	8	4	2	II	3606.85*...	8	6?	4?	3?	II?
3534.85....	1	4	2	1	II A	3609.42....	3	3	1	.....	III
3538.36....	3	.....	.....	.....	V E	3616.86....	3	2	1	.....	III
3540.66....	1	5	3	1	II A	3617.44....	1	1	tr	.....	III
3542.77....	1	3	2	1	II A	3621.35....	2	.....	.....	.....	V E
3543.62....	8	6	5	3	II	3622.79....	2	1	tr	.....	III
3545.32....	12	.....	.....	.....	V E	3628.53....	1	1	1	.....	III
3545.49....	8	6	5	3	II	3629.46....	2	2	1	.....	III
3551.67....	3	3	2	tr	III	3634.06....	3	3	2	.....	III
3552.80....	1	1	tr	.....	III	3635.99....	3	2	1	.....	III
3553.43....	6	6	5	3	II	3637.10....	1	1	1	.....	III
3555.31....	3	5	4	1	III	3637.89....	3	1	.....	.....	IV
3555.87....	2	3	3	1	II	3638.50....	2	2	1	.....	III
3556.40....	4	4	3	1	II	3639.16....	6	5	3	2	II
3556.96....	15	tr	.....	.....	V E	3640.20....	2	2	1	.....	III
3557.34....	2	2	1	.....	III	3641.24....	4	4	3	1	II
3560.74....	3	1	tr	.....	III	3643.25....	1	1	tr	.....	III
3561.55....	1	1	tr	.....	III	3643.99....	5	5	3	1	II
3562.29....	2	2	1	.....	III	3644.49....	1	2	1	.....	III A
3563.54....	2	2	1	.....	III	3644.87....	8	8	6	3	II
3563.67....	1	1	.....	.....	IV	3645.68....	3	3	1	tr	II
3565.20....	1	3	2	tr	III A	3647.4.....	3	3	1	tr	II
3566.32....	4	4	2	tr	III	3648.50....	tr	tr	.....	.....	IV
3569.07....	3	3	1	.....	III	3649.08....	5	5	3	1	II
3569.19....	1	3	2	1	II A	3652.54....	2	2	1	tr	III
3571.16....	4	4	2	1	II	3654.82....	2	1	tr	.....	III
3571.36....	2	2	1	.....	III	3656.81....	6	4	2	1	II
3571.80....	5	5	3	1	II	3657.62....	2	6	5	4	I A
3572.45....	1	2	1	.....	III A	3659.60....	2	1	tr	.....	III
3572.77....	2	2	1	.....	III	3661.52....	2	1	1	.....	III
3573.65....	5	5	3	1	II	3662.16....	1	1	tr	.....	III
3574.90....	3	4	2	1	II	3663.71....	15	8	5	4	II
3575.27....	3	3	1	.....	III	3665.28....	8	6	3	2	II
3578.01....	4	4	2	1	II	3667.89....	15	8	5	4	II
3579.24....	2	2	1	.....	III	3669.58....	2	.....	.....	.....	V E
3579.46....	1	tr	.....	.....	IV	3671.37....	10	8	6	6	I

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace High Temp.	Furnace Medium Temp.	Furnace Low Temp.	Class
3672.55	8	6	3	2	II
3673.57	12	10	5	4	II
3675.64	3	3	1	.....	III
3675.89	20	20r	20	20	I
3676.84	10	8	4	2	II
3677.23	2	6	6	6	I A
3680.25	15	6	5	3	II
3683.30	30	30R	20	20	I
3684.50	3	3	2	1	II
3686.42	8	8	6	5	I
3686.89	1	1	tr	.....	III
3687.63*	12?	6?	5?	3?	II?
3688.23	50	50R	30r	20	II
3690.49	40	40R	20	20	II
3692.40	50	50R	30r	20	II
3694.79	3	4	2	1	II
3695.50	30	10	6	4	II
3696.03	40	50R	25r	20	II
3699.63	3	4	3	1	II
3700.49	3	.....	.....	.....	V E
3700.78	tr	1	tr	.....	III A
3703.73	100	100R	40r	25	II
3704.16	2	3	2	1	II
3704.85	60	60R	25	20	II
3705.20	30	30R	15	20	I
3705.97	1	1	tr	.....	III
3706.19	4	4	3	2	II
3708.87	6	5	4	2	II
3711.56	1	1	tr	.....	III
3713.46	1	1	tr	.....	III
3713.70	1	1	tr	.....	III
3714.11	5	8	8	8	I A
3715.00	1	1	1	.....	III
3715.61	10	.....	.....	.....	V E
3717.69	1	1	tr	.....	III
3718.26	2	.....	.....	.....	V E
3719.05	4	2	1	.....	III
3721.07	1	1	tr	.....	III
3721.55*	3	6	5	4	I A
3722.14	4	4	2	1	II
3722.35	3	1	1	.....	III
3723.47	3	3	2	tr	III
3723.71	1	1	tr	.....	III
3727.48	10	.....	.....	.....	V E
3728.48	2	.....	.....	.....	V E
3729.18	4	4	3	1	II
3730.33*	3	6	4	2	II A
3731.17	2	1	tr	.....	III
3732.21	1	5	4	2	II A
3732.90	10	.....	.....	.....	V E
3734.57	5	5	3	1	II
3737.60	1	5	4	2	II A
3738.11	5	4	3	1	II
3738.89	8	8	5	2	II
3740.39	6	5	3	1	II
3741.63	6	5	3	1	II
3744.04	1	1	1	.....	III
3746.00	8	.....	.....	.....	V E
3747.26	3	4	4	2	II
3748.11	8n	5	3	1	II
3750.27	1	1	tr	.....	III
3751.07	6	.....	.....	.....	V E
3751.95	5	8	6	4	II A
3753.44	4	3	1	tr	II
3755.85	4	3	1	tr	II
3756.18	3	5	4	2	II
3757.04	tr	tr	.....	.....	IV
3758.70	2	2	1	tr	II
3758.95	1	1	tr	.....	III
3759.45	4	3	1	tr	II
3760.95	3	4	3	2	II
3761.56	3	3	2	1	II
3763.29	6	8	5	2	II
3764.95	2	1	tr	.....	III
3765.74	1	1	tr	.....	III
3766.55	2	2	1	tr	II
3769.21	4	4	3	1	II
3769.98	1	1	tr	.....	III
3770.15	2	1	1	.....	III
3770.67	3	6	5	2	II A
3771.11	8	.....	.....	.....	V E
3771.32	1	4	3	1	II A
3771.81	1	5	5	4	I A
3772.29	2	1	tr	.....	III
3772.87	2	1	tr	.....	III
3774.25	3	1	tr	.....	III
3775.33	3	5	3	1	II
3775.82	4	3	2	tr	III
3776.30	4	3	2	1	II
3777.02	2	3	2	tr	III
3777.30	2	6	6	6	I A
3777.61	1	1	tr	.....	III
3778.46	2	.....	.....	.....	V E
3778.82	25	25R	20	20	I
3779.78	4	6	4	2	II
3781.55	3	5	3	2	II
3781.89	1	1	1	.....	III
3782.71	3	3	2	1	II
3783.08	1	1	1	.....	III
3784.83	2	5	7	6	I A
3784.95	1	1	tr	.....	III
3787.30	5	4	3	1	II

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace: High Temp.	Furnace: Medium Temp.	Furnace: Low Temp.	Class	λ (Exner and Haschek)	Arc	Furnace: High Temp.	Furnace: Medium Temp.	Furnace: Low Temp.	Class
3787.68....	3	3	3	1	II	3835.70....	4	6	6	3	II
3788.93....	1	1	1	.....	III	3836.19....	5	5	6	4	I
3790.47....	20	20R	20	20	I	3836.63....	1	tr	.....	.....	IV
3790.62....	8	8	5	3	II	3839.11....	10	7	7	6	I
3791.46....	2	8	6	5	I A	3839.52....	8	5	4	2	II
3793.79....	8	12	12	15	I A	3840.25....	4	5	4	3	I
3794.51....	2	1	tr	.....	III	3840.85....	60r	60R	40R	30	II
3795.12....	50	50R	35r	35	II	3842.02*....	5	12r	8	12	I A
3796.63....	3	3	1	tr	II	3842.84....	3	5	4	2	II
3798.39....	4	4	4	4	I	3843.10....	2	3	2	1	II
3798.80....	2	4	1	.....	III A	3843.61....	4	6	5	2	II
3799.41....	1	tr	.....	.....	IV	3844.58....	20	20r	20	20	I
3800.10....	25	25R	20	20	I	3845.01....	4	4	4	2	II
3803.01....	2	3	2	tr	III	3846.11....	3	2	1	1	II
3803.60....	25	25R	20	20	I	3847.49....	20	20R	20	20	I
3803.93....	6	6	5	2	II	3849.43....	6	5	5	4	I
3804.03....	6	10	8	10	I A	3851.34....	5	4	4	3	I
3804.72....	3	3	2	.....	III	3852.25....	2	4	3	2	II A
3805.05....	2	3	2	tr	III	3854.23....	1	1	1	.....	III
3806.92....	8	6	5	4	II	3855.50....	30	30R	30r	30	I
3807.63....	20	20R	20	20	I	3856.08....	60r	60R	50R	50	I
3808.26....	3	1	tr	.....	III	3858.82....	5	8	6	4	II A
3808.67....	40	40R	25r	25	II	3859.50....	6	8	7	4	II
3809.23....	1	1	tr	.....	III	3861.77....	6n	6	5	3	II
3809.74....	15	15	15	15	I	3862.40....	12	12r	12	15	I
3811.47....	2	1	1	.....	III	3864.02....	6	6	5	3	II
3813.63....	60	60R	25r	25	II	3864.26....	3	3	3	4	I
3815.66....	10	12	12	12	I	3864.70....	1	1	.....	.....	IV
3818.00....	8	12	12	15	I A	3865.05....	35	30R	25r	25	I
3818.12....	4	4	3	1	II	3867.48....	2	4	3	1	II A
3818.41....	60	60R	30r	30	II	3867.75....	15	15r	15	15	I
3818.91....	1	1	tr	.....	III	3870.73....	2	3	2	1	II
3820.11....	15	15r	15	15	I	3871.20....	8	6	6	4	I
3821.65....	15	15r	15	15	I	3872.91....	4n	6	4	2	II
3822.21....	30	30R	20r	20	I	3873.78....	4	5	4	2	II
3822.85....	1	1	tr	.....	III	3874.50....	1	1	1	.....	III
3823.05....	15	15r	15	15	I	3875.22....	35	30R	25r	25	I
3823.40....	15	15r	15	15	I	3875.55....	3	5	6	4	I
3823.55....	1	2	1	.....	III A	3876.02....	20	20R	20r	20	I
3823.92....	4	3	1	tr	II	3876.26....	20	20R	20r	20	I
3824.14....	5	6	6	3	II	3876.84....	1	1	tr	.....	III
3825.18....	1	1	tr	.....	III	3879.38*....	2?	4?	3?	?	III?
3825.47....	4	3	2	1	II	3879.80*....	3?	2?	2?	?	III?
3826.90....	6	8	5	3	II	3884.06....	3	3	3	1	II
3828.70....	60r	60R	30r	30	II	3884.60....	4	4	3	1	II
3828.93....	4	3	2	1	II	3885.00....	2	.....	.....	.....	V E
3830.44....	2	2	1	.....	III	3885.70....	1	1	.....	.....	IV
3831.99....	3	3	2	1	II	3885.93....	2	2	2	tr	III
3832.99....	4	3	2	.....	III	3886.74....	6	6	5	4	I
3833.36....	3	3	2	.....	III	3888.20....	2	2	1	.....	III
3834.95....	tr	tr	.....	.....	IV	3888.47....	3	3	2	tr	III

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
3889.37....	1	1	tr	.....	III	3936.47....	5	5	6	5	I
3890.39....	25	25R	20	25	I	3937.69....	3	3	2	1	II
3891.30*...	4	3	2	1	II	3938.35....	3	2	1	tr	II
	2	4	3	1	II A	3939.04....	2n	2	1	tr	II
3892.63....	2	2	1	tr	II	3939.47....	4	4	3	1	II
3893.03....	25	25R	20	25	I	3940.75....	2	2	1	tr	II
3893.89....	1	1	tr	.....	III	3941.43....	3	3	2	1	II
3894.20....	4	4	3	2	II	3942.18....	6	6	5	3	II
3896.31*...	6	10	8	5	II	3943.80....	12	10	10	8	I
3896.80....	2	2	1	.....	III	3944.66....	1	1	tr	.....	III
3896.96....	2	2	1	.....	III	3945.32....	2	2	1	.....	III
3897.23....	6	4	3	2	II	3946.03....	1	1	tr	.....	III
3898.08*...	6	4?	3?	1	II	3950.39....	4	4	2	tr	III
3898.41....	5	4	3	1	II	3952.13....	6	.....	.....	.....	V E
3899.26....	4	.....	.....	.....	V E	3963.89....	4	2	1	tr	II
3900.29....	6	4	3	2	II	3964.65....	2	1	tr	.....	III
3901.29....	6	4	3	2	II	3968.25....	3	.....	.....	.....	V E
3901.83....	2	2	1	tr	II	3972.12....	2	2	1	.....	III
3902.41....	50r	50R	40R	40	I	3973.53....	2	2	1	.....	III
3902.68....	3	4	4	3	I	3975.50....	1	1	tr	.....	III
3903.38....	4	.....	.....	.....	V E	3979.30....	4	3	2	tr	III
3904.36....	1	3	2	1	II A	3979.56....	4	3	2	tr	III
3904.59*...	2	2	1	.....	III	3980.69....	3	2	1	.....	III
	3	3	2	tr	III	3984.50....	6	6	3	1	II
3906.90....	6	6	6	6	I	3984.76....	6	6	4	2	II
3907.32....	2n	1	1	tr	II	3988.98....	5	5	3	1	II
3908.47....	4n	3	2	tr	III	3990.77....	20	15	12	10	I
3909.55....	tr	tr	.....	.....	IV	3991.24....	1	1	tr	.....	III
3909.81....	4	4	2	tr	III	3992.98....	12	8	6	6	I
3910.03*...	20	20R	20r	25	I	3995.05....	1	1	1	.....	III
3910.93....	5	6	6	5	I	3997.28....	3	.....	.....	.....	V E
3912.37....	10	8	8	8	I	3998.91....	15	12	12	8	I
3913.01....	4	8	6	4	II A	4000.25....	1	1	tr	.....	III
3913.71....	2	1	tr	.....	III	4001.81....	1	1	.....	.....	IV
3914.01....	1	2	2	1	II A	4003.10....	2	.....	.....	.....	V E
3914.46....	5	5	5	3	I	4003.33....	tr	tr	.....	.....	IV
3915.26....	2	1	1	tr	II	4003.69....	2	1	.....	.....	IV
3915.51....	2	2	1	tr	II	4005.88....	6	.....	.....	.....	V
3916.53....	3	.....	.....	.....	V E	4009.92....	2	1	1	.....	III
3917.29....	2	2	2	1	II	4011.45....	3	3	1	.....	III
3920.14....	2	2	1	.....	III	4015.21....	1	tr	.....	.....	IV
3920.64....	5	5	5	4	I	4022.05....	3	1	.....	.....	IV
3922.09....	6	6	6	6	I	4023.32....	4	2	.....	.....	IV
3922.61....	12	12	12	12	I	4023.54....	5	.....	.....	.....	V E
3924.83....	10	8	5	4	II	4030.05....	2	6	5	tr	III A
3925.40....	10	15r	15	20	I	4031.39....	2	2	.....	.....	IV
3926.82....	1	1	1	.....	III	4032.02....	5	2	.....	.....	IV
3930.13....	10	6	6	6	I	4032.64....	1	tr	.....	.....	IV
3931.50....	5	4	4	2	II	4033.00....	2	6	6	tr	III A
3934.20....	20	15r	15	15	I	4034.86....	1	4	2	.....	III A
3935.30....	6	6	4	2	II	4035.76....	4	.....	.....	.....	V E

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4036.90	2	....	....	....	V E	4124.24	5	6	3	....	III
4040.46	2	1	....	....	IV	4128.30	60	60R	35	40	I
4041.75	3	....	....	....	V	4129.01	5	4	2	....	III
4042.80	5	3	1	....	III	4131.35	1	6	4	....	III A
4048.76	4	8	8	3	II A	4132.15	60	60R	35r	40	I
4051.12	10	6	2	....	III	4133.95	3	6	3	....	III A
4051.58	12	6	2	....	III	4134.65	60	60R	35r	40	I
4052.62	1	5	4	tr	III A	4136.25	4	3	1	....	III
4053.43	3	2	tr	....	IV	4136.56	3	8	8	1	III A
4057.26	10	4	2	....	III	4139.42	4	4	tr	....	IV
4064.13	10	5	1	....	IV	4141.52	2	1	....	....	IV
4067.89	3	1	....	....	IV	4142.00	2	5	3	tr	III A
4068.15	4	8	8	3	II A	4142.81	2	6	4	tr	III A
4070.93	4	6	5	2	II	4143.06	2	2	1	....	III
4071.68	8	5	2	....	III	4149.01	2	5	5	tr	III A
4072.31	3	3	1	....	III	4150.86	2	1	....	....	IV
4083.09	4	4	2	....	III	4152.84	2	1	....	....	IV
4090.80*	25	12	?	12	I	4153.50	2	7	6	tr	III A
4092.11	3	3	1	....	III	4156.02	1	5	2	....	III A
4092.55	8	8	6	....	III	4158.15	1	3	1	....	III A
4092.89	50	50R	30r	40	I	4159.85	8	10	15	10	I
4093.65	5	6	4	....	III	4160.56	1	5	2	....	III A
4094.44	3	2	....	....	IV	4169.45	2	2	tr	....	IV
4095.69	25	15	15	7	II	4171.49	3	4	tr	....	IV
4097.09	3	2	....	....	IV	4174.20	5	4	2	....	III
4099.99	60	60R	35r	40	I	4175.32	1	3	tr	....	IV A
4102.37	20	15	15	6	II	4177.26	2	1	....	....	IV
4103.56	1	1	....	....	IV	4179.61	15	15	20	15	I
4104.53	12	7	2	....	III	4181.05	1	1	....	....	IV
4104.94	15	12	5	....	III	4182.26	2	2	....	....	IV
4105.37	60	60R	30r	35	I	4182.81	10	8	12	10	I
4107.63	4	4	2	....	III	4190.03	12	12	15	12	I
4108.37	5	4	1	....	III	4191.71	10	10	9	4	II
4109.20	2	2	....	....	IV	4195.77	1	1	....	....	IV
4109.98	50	50R	30r	40	I	4197.86	2	2	....	....	IV
4111.98	100R	100R	50R	50	I	4198.80	4	8	8	2	III A
4112.53	5	4	1	....	III	4200.35	4	7	7	1	III A
4113.70	12	12	10	tr	III	4201.05	1	6	5	tr	III A
4114.70	3	2	....	....	IV	4210.03	20	15	20	15	I
4115.36	60	60R	30r	40	I	4216.54	1	4	2	1	II A
4115.6	2	3	1	....	III	4218.88	4	10	10	2	III A
4116.64H	50	50R	50r	30	I	4219.67	2	6	4	tr	III A
4116.85H	4	15	15	10	I A	4222.49	2	1	....	....	IV
4118.37*	8	6	2	....	III	4223.14	1	1	....	....	IV
4118.81	8	8	8	tr	III	4224.28	5	3	1	....	III
4119.25	1	1	....	....	IV	4227.90	4	4	1	....	III
4119.62	8	8	10	1	III	4229.86	4	3	1	....	III
4120.71	8	8	8	tr	III	4232.66	15	9	4	....	III
4121.15	1	tr	....	....	IV	4233.15	12	7	3	....	III
4123.34	6	4	1	....	III	4234.19	12	10	15	10	I
4123.71	60	60R	35r	40	I	4234.70	8	8	15	10	I

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4235.91....	10	6	2	.....	III	4355.14....	5	5	1	.....	IV
4236.77....	1	4	2	.....	III A	4356.12....	10	12	15	15	I
4239.13....	2	1	.....	.....	IV	4356.96....	1	1	.....	.....	IV
4240.25....	3	3	tr	.....	IV	4357.64....	2	2	.....	.....	IV
4240.52....	4	6	2	.....	III	4360.76....	3	3	.....	.....	IV
4241.48....	3	3	1	.....	III	4361.58....	2	2	.....	.....	IV
4246.85....	1	1	.....	.....	IV	4363.52....	1	1	.....	.....	IV
4252.96....	1	1	.....	.....	IV	4363.70....	5	12	12	4	II A
4257.51....	6	4	2	.....	III	4364.39....	4	2	.....	.....	IV
4259.46....	8	8	10	8	I	4365.90....	3	2	.....	.....	IV
4261.34....	2	1	.....	.....	IV	4368.23....	10	10	10	15	I
4262.29....	6	5	2	.....	III	4368.79....	4	3	.....	.....	IV
4265.28*...	8n	10	3	.....	III	4369.24....	2	2	.....	.....	IV
4266.06....	1	tr	.....	.....	IV	4373.42....	4	4	tr	.....	IV
4267.47....	1	tr	.....	.....	IV	4374.01....	4	5	1	.....	IV
4268.81....	20	12	8	1	III	4375.25....	1	1	.....	.....	IV
4269.90....	5	4	1	.....	III	4375.50....	4	2	.....	.....	IV
4270.48....	4	2	.....	.....	IV	4376.97....	1	tr	.....	.....	IV
4271.69....	12	10	6	tr	III	4378.07....	2	2	.....	.....	IV
4277.13....	12	8	6	tr	III	4379.41....	150r	150R	75r	60	II
4279.10....	2	4	1	.....	III A	4380.74....	4	5	1	.....	IV
4284.25....	15	10	8	tr	III	4381.20....	1	4	1	.....	IV A
4286.57....	5	5	2	.....	III	4384.36....	1	9	6	1	III A
4287.95....	4	2	.....	.....	IV	4384.91....	125r	125R	60r	50	II
4288.96....	1	2	.....	.....	IV A	4385.50....	1	1	.....	.....	IV
4291.47....	4	4	1	.....	III	4387.40....	3	8	3	.....	III A
4292.00....	15	10	4	.....	III	4390.19....	100	100R	50r	40	II
4296.29....	15	6	3	.....	III	4390.81....	1	1	.....	.....	IV
4297.82....	12	5	3	.....	III	4391.85....	2	2	.....	.....	IV
4298.19....	12	8	3	.....	III	4392.27....	5	12	15	5	II A
4302.28....	tr	1	.....	.....	IV A	4393.26....	4	4	1	.....	III
4303.68....	3	1	.....	.....	IV	4394.03....	4	8	5	.....	III A
4305.61....	3	3	.....	.....	IV	4394.99....	3	4	2	.....	III
4306.40....	15	12	15	15	I	4395.45....	80	80R	40	35	II
4307.36....	12	10	12	12	I	4397.54....	1	tr	.....	.....	IV
4309.67....	2	1	.....	.....	IV	4399.59....	2	3	1	.....	III
4309.99....	20	20r	20	15	I	4400.78....	60	60r	30	30	II
4314.06....	3	2	.....	.....	IV	4403.85....	4	5	2	.....	III
4330.26....	30	30r	20	25	I	4405.23....	4	10	8	1	III A
4332.56....	1	1	.....	.....	IV	4406.30*...	6	20	5	.....	III A
4333.03....	30	30r	20	20	I	4406.88....	80	80R	50r	50	I
4334.28....	4	8	2	.....	III A	4407.80....	70	70R	40r	40	I
4336.30....	2	1	.....	.....	IV	4408.35....	70	70R	40r	40	I
4341.21....	40	40r	20	25	I	4408.70....	90	90R	60r	50	I
4342.37....	4	5	2	.....	III	4412.33....	12	12	15	10	I
4343.00....	6	4	2	.....	III	4413.86....	2	6	2	.....	III A
4350.88....	1	1	.....	.....	IV	4414.73....	2	2	.....	.....	IV
4351.00....	2	12	6	tr	III A	4416.63....	20	20r	20	20	I
4352.64....	2	1	.....	.....	IV	4416.80....	2	6	1	.....	IV A
4353.08....	50	50R	30r	40	I	4420.12....	12	12	15	12	I
4353.51....	2	1	.....	.....	IV	4421.79....	20	20r	20	20	I

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4422.41	3	3	.....	.....	IV	4492.49*	1	2	.....	.....	IV A
4422.65	2	1	.....	.....	IV	4495.17	1	1	.....	.....	IV
4423.39*	8	20	8	tr	III A	4496.25	8	8	2	.....	III
4424.10	2	1	.....	.....	IV	4497.03H	5	6	2	.....	III
4424.75	4	10	2	.....	III A	4497.55	2	1	.....	.....	IV
4425.90	4	8	2	.....	III A	4498.30	tr	1	.....	.....	IV A
4426.20	20	20r	20	20	I	4501.01	1	1	.....	.....	IV
4427.48	5	4	2	.....	III	4501.44	1	1	.....	.....	IV
4428.70	15	12	15	15	I	4502.18	8	10	6	tr	III
4429.98	15	15	20	20	I	4506.30H	2	2	.....	.....	IV
4430.71	3	4	.....	.....	IV	4506.41H	1	tr	.....	.....	IV
4433.05*	1	6	1	.....	IV A	4506.77	2	2	.....	.....	IV
4434.73	5	7	2	.....	III	4509.49	3	3	.....	.....	IV
4436.30	15	15	15	20	I	4511.65	2	2	.....	.....	IV
4438.01	20	20r	20	25	I	4513.81	2	2	.....	.....	IV
4439.15	1	1	.....	.....	IV	4514.39	6	5	2	.....	III
4441.89	25	25r	20	30	I	4515.74	2	2	.....	.....	IV
4443.40	5	3	.....	.....	IV	4517.73*	3	1	.....	.....	IV
4444.40	20	20r	20	25	I	4520.35	3	10	2	.....	III A
4445.98	1	1	.....	.....	IV	4520.71	2	.....	.....	.....	V E
4449.73	5	7	3	.....	III	4523.03	tr	tr	.....	.....	IV
4451.10	4	3	.....	.....	IV	4524.41	15	10	5	.....	III
4452.23	20	12	12	1	III	4525.34	5	5	1	.....	IV
4452.89	2	3	.....	.....	IV	4528.18	5	2	.....	.....	IV
4453.31	1	1	.....	.....	IV	4529.47	4	2	.....	.....	IV
4456.69	3	1	.....	.....	IV	4529.80	8	8	3	.....	III
4457.67	15	15	20	30	I	4530.99	4	1	.....	.....	IV
4457.96	8	8	3	.....	III	4534.11	4	1	.....	.....	IV
4458.58	1	1	.....	.....	IV	4535.74	1	1	.....	.....	IV
4459.99	30	30R	25	35	I	4537.84	6	6	1	.....	IV
4460.58	50	50R	30r	40	I	4540.19	6	5	1	.....	IV
4461.20	4	3	.....	.....	IV	4545.59	25	15	8	1	III
4462.59	20	12	10	1	III	4549.80	10	5	.....	.....	IV
4464.44	2	2	.....	.....	IV	4552.04	3	4	tr	.....	IV
4464.94	2	3	.....	.....	IV	4553.25	7	4	.....	.....	IV
4465.69	2	3	.....	.....	IV	4560.95	20	12	6	tr	III
4467.05	2	4	.....	.....	IV A	4570.62	6	4	1	.....	III
4467.82	1	1	.....	.....	IV	4572.01	15	8	5	.....	III
4468.20	8	9	3	.....	III	4577.38	40	30r	25	35	I
4468.96	4	4	1	.....	III	4578.90	15	10	4	.....	III
4469.91	15	10	8	1	III	4579.29	7	5	1	.....	IV
4471.95	1	1	.....	.....	IV	4580.62	40	30r	25	35	I
4473.43	1	1	.....	.....	IV	4581.45	2	2	.....	.....	IV
4474.26	10	10	3	.....	III	4583.98	5	3	1	.....	III
4474.93	12	12	5	tr	III	4586.11	2	2	tr	.....	IV
4476.08	2	3	.....	.....	IV	4586.59	50	30R	30	40	I
4480.21	6	6	2	.....	III	4588.98	1	tr	.....	.....	IV
4489.09	20	15	8	tr	III	4591.43	12	4	tr	.....	IV
4491.00	5	6	2	.....	III	4594.36	60	40R	40	50	I
4491.35	2	3	1	.....	III	4603.17	2	1	.....	.....	IV
4491.64	1	1	.....	.....	IV	4606.33	15	15	20	15	I

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4609.79	4	3	1	.....	III	4784.68	5	15	15	5	II A
4611.08	2	4	2	.....	III A	4786.72	20	8	4	.....	III
4611.91	2	2	.....	.....	IV	4793.12	3	3	.....	.....	IV
4619.88	8	2	.....	.....	IV	4795.30	3	1	.....	.....	IV
4619.97H	25	20	20	15	I	4797.12	20	8	4	.....	III
4624.55	8	12	8	1	III	4798.14	2	3	.....	.....	IV
4626.64	7	12	7	1	III	4799.20	1	1	.....	.....	IV
4635.34	15	10	20	15	I	4799.97	5	12	15	7	II A
4636.32	2	2	.....	.....	IV	4807.72	25	8	5	.....	III
4640.25	8	10	6	tr	III	4819.20	2	1	.....	.....	IV
4640.92	7	10	5	tr	III	4827.63	30	25	30	30	I
4644.69	3	4	2	.....	III	4828.99	1	1	.....	.....	IV
4646.16	1	4	3	.....	III A	4830.86	1	1	.....	.....	IV
4646.60	15	12	12	1	III	4831.82	35	35	30	30	I
4666.31*	4	3?	3?	.....	III?	4832.61	30	30	25	25	I
4670.70	25	15	20	3	III	4833.20	3	6	1	.....	IV A
4687.08*	6	?	?	.....	?	4833.99	1	tr	.....	.....	IV
4699.49*	3	?	?	.....	?	4843.17	2	2	.....	.....	IV
4705.26*	4	?	?	.....	?	4848.78	3	4	1	.....	III
4706.35*	8	5?	?	.....	?	4849.00	1	tr	.....	.....	IV
4706.77*	12	5?	?	.....	?	4851.69	40	40r	30	30	I
4707.63*	4	8?	2?	.....	III A	4859.31	2	1	.....	.....	IV
4709.91*	4	4?	?	.....	?	4862.79	5	5	1	.....	IV
4710.75*	12	4?	?	.....	?	4864.91	40	30r	25	20	I
4714.30*	10	?	?	.....	?	4875.65	40	30r	25	25	I
4716.10*	5	5?	?	.....	?	4877.40	tr	1	.....	.....	IV A
4717.89	10	5	1	.....	IV	4880.74	8	12	5	.....	III
4721.75	6	3	1	.....	III	4881.73	50	40R	30	30	I
4723.09	8	4	1	.....	III	4882.38	2	4	1	.....	III A
4729.71	6	5	2	.....	III	4885.81	2	2	.....	.....	IV
4730.59	3	3	1	.....	III	4887.00	2	6	2	.....	III A
4737.92	1	1	.....	.....	IV	4890.29	1	1	.....	.....	IV
4738.52	1	1	.....	.....	IV	4891.41	1	1	.....	.....	IV
4739.29	1	2	.....	.....	IV A	4891.80	4	4	1	.....	III
4742.81	5	4	tr	.....	IV	4894.41	4	4	1	.....	III
4746.81	5	5	1	.....	IV	4896.60	1	4	.....	.....	IV A
4747.33	1	1	.....	.....	IV	4900.21	tr	1	.....	.....	IV A
4748.72	7	7	2	.....	III	4900.81	6	4	tr	.....	IV
4751.22	8	9	2	.....	III	4904.58*	12	12	4	.....	III
4751.80	6	6	2	.....	III	4905.10	3	3	tr	.....	IV
4754.19	7	6	1	.....	IV	4906.09	tr	1	.....	.....	IV A
4757.55H	4	4	1	.....	III	4908.86	1	2	.....	.....	IV A
4757.68H	8	8	2	.....	III	4916.42	2	1	.....	.....	IV
4758.94	2	4	1	.....	III A	4925.84	10	10	8	1	III
4765.86	1	1	.....	.....	IV	4932.21	4	8	4	.....	III A
4766.81	10	8	3	.....	III	4933.80	1	1	.....	.....	IV
4773.30	1	tr	.....	.....	IV	4942.98	1	2	.....	.....	IV A
4776.54H	10	8	3	.....	III	4966.27	2	1	.....	.....	IV
4776.70H	5	4	1	.....	III	5002.50	4	4	.....	.....	IV
4778.61	tr	tr	.....	.....	IV	5014.79	5	3	1	.....	III
4781.55	tr	1	.....	.....	IV A	5047.45*	1	2?	1?	.....	IIIA?

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.	
5051.81*	2	1	.....	.....	IV
5064.30*	3	.....	.....	.....	V
5105.32*	2	3?	1?	.....	III?
5128.70*	7	6?	4?	.....	III
5138.60*	5	3?	2?	.....	III
5148.87*	4	2?	1?	.....	III?
5159.52*	3	?	?	.....	III?
5166.93	1	1	.....	.....	IV
5170.11	1	1	tr	.....	III
5176.95	4	2	1	.....	III
5178.73	1	1	.....	.....	IV
5179.30	1	tr	.....	.....	IV
5180.96	1	1	.....	.....	IV
5183.05	1	1	.....	.....	IV
5192.22	1	1	.....	.....	IV
5193.20	7	5	4	.....	III
5193.84	1	1	tr	.....	III
5195.00	10	7	2	.....	III
5195.65	5	3	1	.....	III
5206.80	1	1	tr	.....	III
5213.82	1	1	tr	.....	III
5216.76	3	2	tr	.....	IV
5225.90	3	2	1	.....	III
5233.87	2	2	tr	.....	IV
5234.26	8	4	2	.....	III
5240.35	1	1	tr	.....	III
5241.03	9	5	2	.....	III
5261.12	1	1	.....	.....	IV
5271.20	1	1	.....	.....	IV
5272.87	1	1	.....	.....	IV
5282.70	1	1	.....	.....	IV
5330.58	1	3	1	.....	III A
5353.56	5	3	1	.....	III
5383.61	2	1	.....	.....	IV
5385.33	3	1	tr	.....	III
5388.50	1	1	tr	.....	III
5398.12	1	tr	.....	.....	IV
5402.17	8	5	2	.....	III
5415.47	10	6	2	.....	III
5418.29	2	1	.....	.....	IV
5424.28	4	3	1	.....	III
5434.40	3	2	tr	.....	IV
5437.89	1	1	.....	.....	IV
5458.31	1	1	.....	.....	IV
5487.42	2	3	1	.....	III
5488.10	10	5	3	.....	III
5490.19	2	2	1	.....	III
5505.09	2	3	1	.....	III
5507.95	8	6	2	.....	III
5511.40	1	1	.....	.....	IV
5515.27	1	15	10	6	II A
5517.40	1	8	4	2	II A
5534.02	1	1	.....	.....	IV
5542.91	1	6	4	2	II A
5446.13	2	7	4	tr	III A
5447.26	8	12	9	4	II
5557.67	1	6	5	2	II A
5558.98	3	5	3	.....	III
5561.90	2	4	2	.....	III A
5574.20	1	4	2	1	II A
5584.77	10	10	10	8	I
5586.21	2	2	1	.....	III
5588.69	1	3	1	.....	III A
5592.63	12	10	8	8	I
5593.24	1	10	5	4	II A
5598.10	1	2	1	.....	III A
5601.60	2	3	2	.....	III
5604.41	1	1	.....	.....	IV
5605.18	8	10	10	5	II
5624.87	20	12	12	15	I
5625.18	10	10	10	5	II
5626.27	8	12	10	6	II
5627.85	30	12	15	20	I
5632.71	1	8	6	4	II A
5646.29	10	12	10	5	II
5651.70	1	1	.....	.....	IV
5657.10	1	1	.....	.....	IV
5657.70	12	10	10	6	II
5665.49	1	1	.....	.....	IV
5668.55	12	12	10	6	II
5671.05	30	20	20	20	I
5683.37	2	2	1	.....	III
5687.93	1	1	.....	.....	IV
5691.3	1	1	.....	.....	IV
5698.71	60	30	30	40	I
5703.81	40	20	20	30	I
5704.6	2	1	.....	.....	IV
5706.25	2	1	.....	.....	IV
5707.20	30	20	20	25	I
5707.95	1	1	.....	.....	IV
5709.11	2	2	1	.....	III
5716.37	3	1	.....	.....	IV
5725.80	6	5	2	.....	III
5727.28	60	30	30	40	I
5727.89	20	20	20	8	II
5730.10	tr	1	.....	.....	IV A
5731.50	30	35	30	12	II
5733.29	1	1	.....	.....	IV
5733.63	1	tr	.....	.....	IV
5734.21	5	4	2	.....	III
5737.25	25	20	20	12	II
5743.66	18	20	20	8	II

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
5747.92	2	2	1	.....	III	6135.49	15	15	15	10	II
5749.05	4	4	3	.....	III	6150.32	15	20	25	30	I
5750.89	2	2	1	.....	III	6170.55	8	20	20	15	I A
5752.92	3	4	2	.....	III	6182.06	1	4	2	.....	III A
5761.67	2	7	4	tr	III A	6189.55	3	15	15	4	II A
5772.65	6	6	5	.....	III	6190.70	1	4	2	.....	III A
5776.90	4	15	10	3	II A	6199.40	30	30	30	35	I
5782.81	2	6	3	.....	III A	6214.04	15	20	20	15	I
5783.12	1	1	.....	.....	IV	6214.93	1	1	.....	.....	IV
5783.81	2	2	1	.....	III	6216.52	30	30	30	35	I
5784.64	5	3	1	.....	III	6218.52	3	2	.....	.....	IV
5786.43	7	4	2	.....	III	6221.39	1	7	3	.....	III A
5788.80	3	4	3	.....	III	6224.70	15	20	20	15	I
5790.80	1	2	1	.....	III A	6230.92	30	25	25	30	I
5800.2	2	2	tr	.....	IV	6233.31	12	20	20	15	I A
5807.38	3	2	1	.....	III	6236.49	1	1	.....	.....	IV
5815.00	1	1	.....	.....	IV	6238.38	tr	tr	.....	.....	IV
5817.30	3	4	2	.....	III	6240.30	6	15	15	8	II A
5817.85	5	2	1	.....	III	6243.02	15	20	20	25	I
5826.83	1	1	1	.....	III	6243.37	30	20	20	30	I
5830.95	7	3	1	.....	III	6243.70	3	8	4	.....	III A
5846.65	8	4	1	.....	III	6245.35	2	12	8	3	II A
5850.57	2	4	2	.....	III A	6249.37	tr	1	.....	.....	IV A
5853.96	1	2	tr	.....	IV A	6252.02	30	30	30	30	I
5855.70	tr	1	.....	.....	IV A	6257.03	8	20	20	10	II A
5863.41	tr	1	.....	.....	IV A	6258.73	8	25	30	10	II A
5924.82	2	4	3	.....	III A	6261.39	5	25	20	6	II A
5979.11	2	4	2	.....	III A	6266.49	7	20	20	8	II A
5981.02	2	7	4	tr	III A	6268.98	8	25	30	10	II A
5984.85	1	4	2	.....	III A	6274.80	15	20	20	20	I
6002.52	2	7	4	1	II A	6282.52	2	3	1	.....	III
6002.89	4	10	8	3	II A	6285.32	20	20	20	25	I
6008.90	tr	4	2	.....	III A	6293.02	20	20	20	25	I
6016.34	1	1	.....	.....	IV	6296.69	15	20	20	20	I
6018.16	tr	4	2	.....	III A	6298.89	tr	1	.....	.....	IV A
6022.00	tr	tr	.....	.....	IV	6304.60	2	1	.....	.....	IV
6025.64	1	2	1	.....	III A	6309.89	1	1	.....	.....	IV
6039.95	25	15	15	15	I	6311.70	3	2	1	.....	III
6048.89	tr	2	1	.....	III A	6318.59	tr	1	.....	.....	IV A
6058.33	5	20	10	3	II A	6321.49	2	1	.....	.....	IV
6063.57	tr	1	tr	.....	III A	6324.87	2	3	1	.....	III
6067.47	1	1	tr	.....	III	6327.00	6	8	5	1	III
6081.70	25	20	20	20	I	6339.23	5	7	4	tr	III
6087.70	1	3	1	.....	III A	6344.12	1	1	.....	.....	IV
6090.45	50	25	25	25	I	6349.61	5	7	4	tr	III
6104.91	tr	4	2	.....	III A	6355.72	1	2	1	.....	II A
6107.21	2	8	4	tr	III A	6357.47	4	6	4	.....	III
6111.90	25	25	25	12	II	6358.99	3	4	2	.....	III
6119.70	40	20	20	25	I	6361.42	3	4	2	.....	III
6128.49	2	6	4	tr	III A	6374.67	1	2	1	.....	III A
6135.21	2	4	3	.....	III A	6379.53	3	4	1	.....	III

TABLE I—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
6393.47	2	3	1	.....	III	6543.71	3	15	8	1	III A
6417.19	tr	1	.....	.....	IV A	6550.26	1	1	.....	.....	IV
6418.87	tr	1	.....	.....	IV A	6558.23	2	7	3	tr	III A
6423.50	tr	1	.....	.....	IV A	6566.10	2	8	4	tr	III A
6425.3	1	1	.....	.....	IV	6579.19	1	4	3	.....	III A
6430.68	3	5	3	.....	III	6606.22	5	15	15	3	III A
6431.82	2	4	3	.....	III A	6608.06	2	5	3	.....	III A
6433.37	1	3	2	.....	III A	6623.80	tr	2	tr	.....	IV A
6435.35	1	3	2	.....	III A	6625.10	5	15	15	3	III A
6438.25	tr	1	.....	.....	IV A	6633.53	1	4	1	.....	III A
6445.35	tr	1	.....	.....	IV A	6644.02	tr	2	tr	.....	IV A
6448.02	tr	1	.....	.....	IV A	6662.6	tr	2	tr	.....	IV A
6451.20	tr	1	.....	.....	IV A	6753.20	5	15	15	3	III A
6452.55	8	20	15	4	II A	6766.70	4	12	12	2	III A
6467.19	1	4	2	.....	III A	6785.19	3	10	10	1	III A
6488.22	2	2	tr	.....	IV	6812.63	2	7	6	tr	III A
6490.94	1	1	.....	.....	IV	6830.16*	1	2	2	.....	III A
6504.38	8	20	15	4	II A	6832.67*	1	3	3	.....	III A
6508.96	1	1	tr	.....	III	6842.11*	1	2	2	.....	III A
6531.65	20	20	20	6	II						

REMARKS ON TABLE I

λ	
3217.20	Furnace line may be partly Ti.
3533.87	Components of double line about 0.07 A apart.
3583.85	Wide in furnace and arc. May be double.
3606.85	Blend with Fe.
3687.63	Blend with Fe.
3721.55	Probably double.
3730.33	Wide in furnace and arc. Probably double.
3842.02	Exceptionally strong at low temperature.
3879.38, 3879.80	Disturbed by carbon.
3891.30	Double line, not fully resolved.
3896.31	Probably double.
3898.08	Blend with Fe.
3904.59	Double line, not fully resolved.
3910.03	Probably double. Reversal is stronger on red side.
4090.80	Blended with impurity line on medium temperature plates.
4118.37	Double line, not resolved.
4265.28	Wide in furnace and arc.
4406.30	Probably double.
4423.39	Probably double.

4433.05	Wide in furnace.
4492.49	Wide in furnace.
4517.73	Wide in furnace.
4666.31	Disturbed by carbon.
4687.08 to 4716.10	These lines are in a dense carbon fluting and intensities are uncertain. They are not strong in the furnace and probably belong in Classes III and IV.
4904.58	Probably double.
5047.45 to 5159.52	Disturbed by carbon.
6830.16 6832.67 6842.11	λ's according to Shaw, *Astrophysical Journal*, **30**, 127, 1909.

TABLE II

TEMPERATURE CLASSIFICATION OF CHROMIUM LINES

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
3550.81	4	.....	.....	.....	V	3743.10	5	4	1	.....	III
3558.66	8n	5	1	.....	IV	3743.71	20	8	4	2	II
3566.28	10n	5	1	.....	IV	3744.03	20	6	3	2	II
3572.90	2	2	.....	.....	IV	3744.67	5	4	2	.....	III
3573.80	5	3	1	.....	III	3747.42	2	1	tr	.....	III
3574.19	4	2	1	.....	III	3748.75	5	3	1	.....	III
3574.97	5	2	1	.....	III	3749.15	20	10	5	1	III
3575.06	3	1	.....	.....	IV	3751.34	1	tr	.....	.....	IV
3578.81*	200R	400R	200R	100r	II	3755.99	2	1	tr	.....	III
3584.47	12n	.....	.....	.....	V	3757.30	5	3	1	.....	III
3587.12	2n	.....	.....	.....	V	3757.80	12	5	3	tr	III
3593.64*	160R	320R	160R	80r	II	3758.18	6	4	2	.....	III
3599.54	1	1	.....	.....	IV	3767.60	4	3	tr	.....	IV
3601.81	6	3	2	.....	III	3768.23H	3n	3	1	.....	III
3602.70	1	1	tr	.....	III	3768.37	12	8	3	1	II
3603.89*	3	?	1	.....	III	3768.86	5	4	1	.....	III
3605.49*	140R	280R	140R	70r	II	3769.14	1	1	tr	.....	III
3609.65	3	2	1	.....	III	3786.38	2	1	.....	.....	IV
3610.20	2	1	tr	.....	III	3789.87	4	8	5	2	II A
3613.80	1	1	.....	.....	IV	3790.35	2	1	.....	.....	IV
3615.77	4	10r	5	3	II A	3790.62	5	2	tr	.....	IV
3619.57	2	2	.....	.....	IV	3791.52	7	4	1	.....	III
3632.98	6	5	2	.....	III	3792.29	7	4	1	.....	III
3636.70	10	5	3	1	II	3792.55	1	1	.....	.....	IV
3639.97	15	5	4	1	II	3793.44	7	4	1	.....	III
3640.55	4	3	1	.....	III	3794.00	7	4	1	.....	III
3641.61	3	3	1	.....	III	3794.75	5	3	1	.....	III
3641.99	8	4	2	.....	III	3797.29	7	4	1	.....	III
3646.30	1	1	.....	.....	IV	3797.85	12	6	3	.....	III
3648.66	2	3	1	.....	III	3804.95	15	8	4	1	III
3649.11	10	5	3	tr	III	3806.97	4	1	.....	.....	IV
3654.07	8	4	2	.....	III	3808.06	6	3	1	.....	III
3656.40	10	5	3	tr	III	3810.4	2n	1	.....	.....	IV
3663.01	2	2	1	.....	III	3812.36	5	2	.....	.....	IV
3663.36	5	4	2	.....	III	3814.71	4	1	.....	.....	IV
3666.14	1	1	.....	.....	IV	3815.60	10	5	3	.....	III
3666.78	3	1	.....	.....	IV	3817.96	4	3	2	.....	III
3676.45	2	1	.....	.....	IV	3818.62	8	5	2	.....	III
3679.18	1	1	.....	.....	IV	3819.72	15	6	3	.....	III
3679.97	2	2	1	.....	III	3823.68	8	8	7	4	II
3681.82	1	1	.....	.....	IV	3825.51	10	3	1	.....	III
3685.70	5n	5	3	.....	III	3826.58	10	5	2	.....	III
3686.95	6n	5	2	.....	III	3830.20	15n	.....	.....	.....	V
3687.42	5n	3	1	.....	III	3831.20	5	8	7	3	II A
3687.66	4	4	2	.....	III	3832.50	2	5	4	tr	III A
3713.10	1	1	.....	.....	IV	3834.94	8	3	2	.....	III
3716.68	3n	1	.....	.....	IV	3836.22	4	2	1	.....	III
3730.96	10	10R	10r	8	I	3841.43	20	7	5	1	III
3732.19	12	12R	12r	8	I	3842.22	4n	2	.....	.....	IV

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
3849.10	10	8	4	1	III	3963.85	30	12	9	5	II
3849.45	20n	8	3	.....	III	3969.22	5	5	4	tr	III
3849.60	8	10	7	6	I	3969.90	25	10	9	4	II
3850.20	20	12	4	1	III	3971.41	5	4	3	tr	III
3852.33	8	10	7	6	I	3972.83	2	2	1	.....	III
3853.30	3	2	1	.....	III	3976.44	1	1	.....	.....	IV
3854.36	12	8	3	.....	III	3976.85	25	20	12	4	II
3854.95	4n	1	.....	.....	IV	3978.80	4	5	3	.....	III
3855.41	5	3	2	.....	III	3979.95	3	4	2	.....	III
3855.73	8	5	3	.....	III	3981.41	5	6	3	.....	III
3856.41	5	3	2	.....	III	3984.08	20	12	8	4	II
3857.75	15	10	5	1	III	3984.50	10	8	5	1	III
3859.0	10n	6	3	.....	III	3990.14	6	3	tr	.....	IV
3862.69	3	1	.....	.....	IV	3991.30	20	12	8	4	II
3868.40	2	.....	.....	.....	V	3991.82	10	8	4	tr	III
3870.4	3n	2	1	.....	III	3992.29	1	1	.....	.....	IV
3874.70	10	5	3	.....	III	3992.99	15	10	4	.....	III
3875.3	4n	tr	.....	.....	IV	3994.13	4	4	2	.....	III
3879.39	8	5	2	.....	III	4000.12	2	.....	.....	.....	V
3881.41	5n	2	1	.....	III	4001.61	8	3	tr	.....	IV
3883.48	15	18r	15	10	I	4004.08	2	.....	.....	.....	V
3885.36	15	15r	12	8	I	4012.61	8	2	.....	.....	IV
3886.92	15	15r	12	8	I	4014.81	3	1	.....	.....	IV
3894.20	15	12r	10	7	I	4018.35	3	3	1	.....	III
3897.79	2	tr	.....	.....	IV	4022.40	8	2	.....	.....	IV
3902.24	2	.....	.....	.....	V	4023.90	2	.....	.....	.....	V
3903.05*	12	8?	6?	4?	II?	4025.18	7	6	3	tr	III
3903.29	8	8	7	5	I	4025.63	1	1	.....	.....	IV
3907.91	2	tr	.....	.....	IV	4026.31	10	10	5	1	III
3908.91	25	25R	15	10	II	4027.23	8	8	4	.....	III
3911.97*	10n	3	1	.....	III	4028.21	1	1	.....	.....	IV
3912.13*		4	2	.....	III	4033.44	3	3	2	.....	III
3915.98	6	5	2	.....	III	4037.42	3	3	2	.....	III
3916.41	12	10r	8	6	I	4039.20	10	4	1	.....	III
3917.19	2	1	tr	.....	III	4041.97	2	.....	.....	.....	V
3917.80	4	3	1	.....	III	4042.40	4	3	1	.....	III
3919.32	35r	35R	20r	12	II	4043.86	3	.....	.....	.....	V
3921.21	20	15r	12	9	I	4046.93	3	2	tr	.....	IV
3926.82	3	1	.....	.....	IV	4048.91	10	4	tr	.....	IV
3928.82	25	20r	15	10	I	4049.95	2	1	.....	.....	IV
3941.67	20	15r	12	10	I	4050.20	2	1	.....	.....	IV
3945.64	2	1	.....	.....	IV	4051.49	2	.....	.....	.....	V
3946.10	3	2	tr	.....	IV	4056.19	3	.....	.....	.....	V
3949.00	1	tr	.....	.....	IV	4056.95	2	.....	.....	.....	V
3949.71	2	1	.....	.....	IV	4058.94	10	4	tr	.....	IV
3951.26	3	2	tr	.....	IV	4060.82	2	.....	.....	.....	V
3951.93	2	1	tr	.....	III	4065.88	6	.....	.....	.....	V
3952.55	4	3	1	.....	III	4067.09	10	7	3	.....	III
3953.30	3	2	tr	.....	IV	4075.00	3	1	.....	.....	IV
3958.22	1	tr	.....	.....	IV	4076.20	4	1	.....	.....	IV
3960.91	1	1	tr	.....	III	4077.25	5	5	1	.....	IV

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4077.85	4	1	.....	.....	IV	4183.25	1	1	.....	.....	IV
4081.90	3	2	.....	.....	IV	4185.10	3	4	1	.....	III
4085.20	2	1	.....	.....	IV	4185.53	2	2	.....	.....	IV
4090.50	3	1	.....	.....	IV	4186.51	3	1	.....	.....	IV
4092.35	3	1	.....	.....	IV	4190.31	3	1	.....	.....	IV
4097.80*		5	2	.....	III	4191.45	10	8	3	1	II
4098.11*	20n	7	3	tr	III	4191.94	4	4	1	.....	III
4098.33*		7	3	tr	III	4192.27	5	1	.....	.....	IV
4099.19	4	2	tr	.....	IV	4193.80	8	3	tr	.....	IV
4101.33	4	2	tr	.....	IV	4194.50	2	3	1	.....	III
4104.01	2	1	.....	.....	IV	4195.10	7	2	1	.....	III
4105.00	6	3	1	.....	III	4197.40	7	2	tr	.....	IV
4106.22	2	.....	.....	.....	V	4198.68	8	2	tr	.....	IV
4108.56	3	2	1	.....	III	4200.26	5	3	1	.....	III
4109.73	8	4	2	.....	III	4203.75	10	8	3	.....	III
4111.02*		8	4	tr	III	4204.43	3	4	1	.....	III
4111.51*	20n	6	3	.....	III	4204.64	7	1	.....	.....	IV
4111.82*		3	1	.....	III	4207.10	4	.....	.....	.....	V
4120.78	8	5	2	.....	III	4208.50	6	2	.....	.....	IV
4121.45	4	.....	.....	.....	V	4209.51	10	4	tr	.....	IV
4121.98	7	4	1	.....	III	4209.92	6	5	2	.....	III
4122.35	5	3	1	.....	III	4211.50*	6	5	1	.....	IV
4123.54	10	6	1	.....	IV	4212.81	4n	1	.....	.....	IV
4126.69	18	10	5	2	II	4213.36	4	3	tr	.....	IV
4127.10	3	3	1	.....	III	4216.52	8	6	1	.....	III
4127.46	4	1	.....	.....	IV	4217.75	15	10	3	.....	III
4127.81	5	5	2	.....	III	4221.73	8	2	.....	.....	IV
4128.56	3	.....	.....	.....	V	4222.90	6	6	2	.....	III
4129.36*	20n	10	5	tr	III	4224.68	4	.....	.....	.....	V
4131.55	10	2	.....	.....	IV	4230.68	4	4	1	.....	III
4134.55	3	.....	.....	.....	V	4232.41	3	2	tr	.....	IV
4146.38	4	tr	.....	.....	IV	4233.05	2	2	.....	.....	IV
4146.65	2	1	.....	.....	IV	4234.70	3	3	1	.....	III
4146.86	4	2	.....	.....	IV	4237.90	2	2	tr	.....	IV
4152.93	4	1	.....	.....	IV	4239.12	8	7	2	.....	III
4153.23	4	3	1	.....	III	4240.89	10	8	2	.....	III
4154.00	20	10	5	1	III	4243.01	1	1	.....	.....	IV
4161.55	12	1	.....	.....	IV	4248.45	2	2	tr	.....	IV
4163.79	20	4	1	.....	III	4248.87	2	1	.....	.....	IV
4165.70	10	1	.....	.....	IV	4252.39	2	1	tr	.....	III
4170.00	6	2	.....	.....	IV	4254.51	500R	1000 R	500R	250r	II
4170.40	4	1	.....	.....	IV	4255.70*	6	?	1	.....	III
4171.86	3	3	1	.....	III	4257.54	2	1	.....	.....	IV
4172.95	4	1	.....	.....	IV	4259.32	2	1	.....	.....	IV
4174.36	1	1	.....	.....	IV	4261.51	8	8	3	.....	III
4174.53	1	1	.....	.....	IV	4261.80	4	2	tr	.....	IV
4175.01	15	15	5	1	III	4262.30	4	2	tr	.....	IV
4175.43	3	1	.....	.....	IV	4262.56	2	1	tr	.....	III
4176.16	5	4	1	.....	IV	4263.30	12	5	1	.....	IV
4178.12	3n	.....	.....	.....	V	4267.01	1	1	.....	.....	IV
4179.42	12	6	1	.....	IV	4268.95	2	tr	.....	.....	IV

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace High Temp.	Furnace Medium Temp.	Furnace Low Temp.	Class	λ (Exner and Haschek)	Arc	Furnace High Temp.	Furnace Medium Temp.	Furnace Low Temp.	Class
4270.15....	4	2	tr	.....	IV	4385.15....	20	20r	20	20	I
4273.10....	6	2	1	.....	III	4387.54H..	2	2	1	.....	III
4275.00....	400R	800R	400R	200r	II	4387.64H..	5	4	2	.....	III
4280.57....	12	4	1	.....	III	4391.93....	8	8	8	6	I
4284.90....	2	3	1	.....	III	4392.50....	1	1	.....	.....	IV
4289.90....	350R	700R	350R	175r	II	4393.74....	2	1	.....	.....	IV
4292.14....	6	1	.....	.....	IV	4395.61....	2	1	.....	.....	IV
4293.71....	4	3	1	.....	III	4397.44....	3	3	1	.....	III
4295.91....	15	15	4	.....	III	4400.01....	3	3	1	.....	III
4296.46....	1	tr	.....	.....	IV	4403.55H..	3	3	1	.....	III
4296.80....	1	tr	.....	.....	IV	4403.68H..	5	1	tr	.....	IV
4297.21....	5	5	2	.....	III	4406.46....	2	1	.....	.....	IV
4297.89....	12	2	tr	.....	IV	4410.49....	4	4	1	.....	III
4299.85....	4	3	2	.....	III	4411.15H..	2	1	tr	.....	III
4301.35....	6	2	tr	.....	IV	4411.26H..	5	5	2	.....	III
4305.61....	5	4	2	.....	III	4412.44....	6	10	10	6	I A
4307.67....	1	tr	.....	.....	IV	4414.02....	5	3	1	.....	III
4319.80....	8	6	2	.....	III	4422.8.....	2	1	.....	.....	IV
4320.78....	4	3	1	.....	III	4423.55....	3	4	1	.....	III
4321.44....	3	2	tr	.....	IV	4424.20H..	2	2	1	.....	III
4321.81....	3	2	tr	.....	IV	4424.49....	10	7	3	tr	III
4323.70....	5	1	.....	.....	IV	4425.31....	3	1	.....	.....	IV
4325.25....	15	10	4	.....	III	4428.66....	5	5	2	.....	III
4332.75....	2	1	.....	.....	IV	4430.09....	2	1	.....	.....	IV
4337.74....	30	30R	25	20	I	4430.72....	4	1	tr	.....	III
4338.56....	3	1	.....	.....	IV	4432.35....	7	7	3	.....	III
4338.95....	3n	1	.....	.....	IV	4434.15....	2	2	1	.....	III
4339.62....	40	40R	30r	20	I	4442.45....	4	2	1	.....	III
4339.90....	20	20r	20	12	I	4443.89....	4	1	.....	.....	IV
4340.31....	8	8	3	.....	III	4450.5.....	3n	1	.....	.....	IV
4343.33....	4	3	1	.....	III	4458.72....	12	10	4	tr	III
4344.68....	40	40R	35r	25	I	4459.57....	4n	4	1	.....	III
4345.27....	2	2	.....	.....	IV	4459.92*...	6	?	?	?	?
4346.99....	10	7	3	.....	III	4460.90....	4n	4	1	.....	III
4351.22....	20	20r	20	15	I	4461.50....	1	tr	.....	.....	IV
4351.98....	60	60R	40r	25	I	4462.91....	3	3	1	.....	III
4354.13....	2	2	tr	.....	IV	4464.85....	2	2	tr	.....	IV
4356.95....	4	3	1	.....	III	4465.09....	4	4	1	.....	III
4357.69....	2	1	tr	.....	III	4465.31H..	2n	1	.....	.....	IV
4359.82....	20	20r	20	20	I	4465.53....	5	5	2	.....	III
4363.31....	6	6	3	.....	III	4466.35....	3	2	tr	.....	IV
4368.45....	2	2	tr	.....	IV	4467.74....	4	3	1	.....	III
4371.48....	20	20r	20	20	I	4468.55....	1	1	.....	.....	IV
4373.42....	8	8	8	6	I	4469.99....	1	1	.....	.....	IV
4373.81....	2	.....	.....	.....	V	4473.96....	4n	4	2	.....	III
4374.32....	12	8	4	1	II	4475.50....	8n	8	3	.....	III
4375.49....	8	5	2	.....	III	4477.20....	2n	4	2	.....	III A
4376.95....	3	.....	.....	.....	V	4480.45*...	2	2	tr	.....	IV
4377.69....	4	3	1	.....	III		1	1	.....	.....	IV
4381.30....	6	5	2	.....	III	4483.02....	5	3	1	.....	III
4383.05....	2	2	1	.....	III	4488.21....	5	5	2	.....	III

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4489.62....	5	2	tr	.....	IV	4595.79....	6	1	.....	.....	IV
4490.8*....	2n	1	.....	.....	IV	4600.30....	5	5	3	.....	III
4491.90....	3n	5	3	.....	III	4600.90....	20	20	20	20	I
4492.01....	3	2	1	.....	III	4601.21....	4	4	2	.....	III
4492.50....	6	3	2	.....	III	4613.53....	15	15	15	15	I
4495.50....	2	1	.....	.....	IV	4616.28....	25	25	25	25	I
4497.03....	25	25R	25r	25	I	4619.70....	8	5	2	.....	III
4498.87....	6	6	4	.....	III	4622.10....	10	10	4	.....	III
4500.42....	7	6	4	.....	III	4622.62....	5	3	1	.....	III
4501.25....	6	5	3	.....	III	4622.95....	3	2	tr	.....	IV
4501.90....	3	3	2	.....	III	4626.35....	20	20	20	20	I
4502.43....	1	1	.....	.....	IV	4632.39*....	2	?	.....	.....	IV ?
4503.25....	2	1	.....	.....	IV	4633.49....	2	1	.....	.....	IV
4506.99....	4	1	.....	.....	IV	4637.36....	4	4	2	.....	III
4512.10....	10	8	3	.....	III	4637.95....	4	4	2	.....	III
4514.70....	8	6	2	.....	III	4639.78*....	2	?	.....	.....	IV ?
4515.60....	4	3	1	.....	III	4646.35....	40	40	40	40	I
4521.32....	4	1	.....	.....	IV	4646.68*....	3	2	tr	.....	IV
4525.00....	2	.....	.....	.....	V	4646.99....	3	2	tr	.....	IV
4526.28....	3	2	.....	.....	IV	4648.29....	5	5	2	.....	III
4526.66....	15	12	10	3	II	4649.01....	5	3	tr	.....	IV
4527.53H*.	6	?	?	.....	III ?	4649.61....	5	2	tr	.....	IV
4527.65H*.	4	?	?	.....	III ?	4651.49....	20	20	20	20	I
4530.02....	5	5	2	.....	III	4652.38....	30	30	30	30	I
4530.91....	20	15	10	3	II	4654.94....	3	2	tr	.....	IV
4535.33....	6	6	3	.....	III	4656.38*....	2	?	.....	.....	IV ?
4535.89*....	15	8 ?	6 ?	2	II	4663.53....	7	3	tr	.....	IV
4539.94....	5	5	3	.....	III	4664.05....	8	4	1	.....	III
4540.64....	12	8	5	2	II	4665.00....	8	5	2	.....	III
4540.88....	10	6	3	.....	III	4666.10....	4	1	.....	.....	IV
4541.23....	5	4	3	.....	III	4666.40....	4	3	1	.....	III
4541.65....	4	2	1	.....	III	4666.72....	7	3	1	.....	III
4542.76....	5	3	1	.....	III	4667.34....	2	1	.....	.....	IV
4543.89....	2	2	1	.....	III	4669.52....	6	3	1	.....	III
4544.78....	12	10	6	2	II	4680.70....	4	2	1	.....	III
4545.47....	5	5	3	.....	III	4681.10*....	3	?	?	.....	IV ?
4546.10....	20	20	20	20	I	4689.55....	8	6	2	.....	III
4555.01....	2	2	.....	.....	IV	4694.15....	5	3	1	.....	III
4555.30....	1	1	.....	.....	IV	4695.35*....	3	?	1 ?	.....	III ?
4556.35....	6	3	1	.....	III	4697.25....	5	4	2	.....	III
4563.89....	2	2	tr	.....	IV	4698.71....	20	12	5	1	III
4564.36....	3	.....	.....	.....	V	4700.80....	4	3	tr	.....	IV
4565.70....	12	12	12	12	I	4706.29....	2	1	.....	.....	IV
4569.80....	8	6	2	.....	III	4708.20....	15	6	3	tr	III
4571.28....	1	1	.....	.....	IV	4718.63....	20	8	4	1	III
4571.89....	10	8	4	.....	III	4723.31....	4	3	1	.....	III
4575.30....	2	1	.....	.....	IV	4724.60....	4	3	1	.....	III
4580.26....	20	20	20	20	I	4727.32....	6	4	1	.....	III
4584.30....	2	1	.....	.....	IV	4729.92....	2	1	.....	.....	IV
4586.31....	2	1	.....	.....	IV	4730.90....	8	6	3	.....	III
4591.61....	20	20	20	20	I	4737.52....	10	6	3	.....	III

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
4745.49	2	3	1	.....	III	5122.27	4	5	4	3	I
4752.29	6	2	tr	.....	IV	5123.63	6	8	6	4	I
4754.92	2	2	tr	.....	IV	5139.81	12	2	.....	.....	IV
4755.33	2	2	tr	.....	IV	5144.85*	7	?	?	1	II?
4756.30	15	10	6	1	III	5161.94*	3	?	?	.....	III?
4764.48	5	3	1	.....	III	5166.41	15	3	1	.....	III
4764.87	1	1	tr	.....	III	5177.57	7	2	tr	.....	IV
4766.88	2	1	tr	.....	III	5184.73	10	3	1	.....	III
4767.47	1	tr	.....	.....	IV	5192.18	10	3	1	.....	III
4768.02	3	2	tr	.....	IV	5193.67	4	1	.....	.....	IV
4775.32	1	1	.....	.....	IV	5196.61	15	4	1	.....	III
4789.53	20	12	8	3	II	5200.37	6	2	tr	.....	IV
4790.55	2	4	2	.....	III A	5204.71	150r	120R	70R	50	II
4792.72	15	8	3	.....	III	5206.24	200r	150R	80R	60	II
4796.33	2	1	.....	.....	IV	5208.60	300r	200R	100R	75	II
4801.24	15	9	4	.....	III	5212.40	3	1	.....	.....	IV
4806.48	1	3	1	.....	III A	5214.27	6	2	tr	.....	IV
4810.95	1	2	tr	.....	III A	5221.10	3	1	.....	.....	IV
4814.50	1	2	tr	.....	III A	5221.93	8	3	1	.....	III
4829.53	18	15	9	2	II	5222.85	2	2	tr	.....	IV
4837.06	2	2	1	.....	III	5224.24	3	1	.....	.....	IV
4846.52	1	1	.....	.....	IV	5224.70	3	1	.....	.....	IV
4861.40	4	4	2	.....	III	5225.19	25	10	3	tr	III
4862.01	15	12	6	1	III	5226.00	4	3	1	.....	III
4870.99	20	10	4	1	III	5227.09	4	2	.....	.....	IV
4874.82	1	1	.....	.....	IV	5228.25	3	1	.....	.....	IV
4880.21	1	1	.....	.....	IV	5230.35	2	2	1	.....	III
4885.13	1	3	1	.....	III A	5239.12	5	5	2	tr	III
4885.92H	4	5	3	.....	III	5240.62	3	1	.....	.....	IV
4886.11H	1	2	tr	.....	IV A	5241.62H	1	1	.....	.....	IV
4887.20	20	6	4	1	II	5243.53	7	3	1	.....	III
4887.88	1	1	tr	.....	III	5247.72	40	20r	20	20	I
4888.71	4	4	2	.....	III	5255.08H	10	4	tr	.....	IV
4903.47	8	6	3	.....	III	5255.27H	15	6	1	.....	IV
4921.15	3	2	tr	.....	IV	5261.91	6	2	.....	.....	IV
4922.49	20	10	6	1	III	5264.35	50	30R	30	20	I
4936.50	10	5	2	.....	III	5265.33	8	4	1	.....	III
4942.68	8	30	20	10	II A	5265.90	25.	20r	20	12	I
4954.99	10	5	2	.....	III	5272.18	8	4	1	.....	III
4965.10	6	20	15	8	II A	5273.59	6	2	1	.....	III
5013.49	6	5	2	.....	III	5275.33	20n	12	4	2	II
5022.04	2	10	7	4	II A	5275.85H	15n	12	6	3	II
5048.95	2	8	6	3	II A	5276.20H	20n	12	6	3	II
5052.08	8	10	8	6	I	5278.39	2	.....	.....	.....	V
5066.06	5	2	1	.....	III	5280.48	4	2	.....	.....	IV
5067.87	10	3	1	.....	III	5287.34	4	2	.....	.....	IV
5068.45	2	8	6	3	II A	5296.86	50	25r	25	20	I
5073.10	12	10	8	6	I	5297.48	20n	12	8	3	II
5092.03	3	8	6	3	II A	5298.14H	15n	10	6	2	II
5110.93*	7	3	2?	1?	II?	5298.46	60	30r	30	25	I
5113.30*	5	3	?	1?	II?	5300.89	25	15	15	12	I

TABLE II—*Continued*

λ (Exner and Haschek)	Arc	Furnace			Class	λ (Exner and Haschek)	Arc	Furnace			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
5304.33....	4	1	.....	.....	IV	5720.03....	2	2	1	.....	III
5313.02....	5	2	tr	.....	IV	5729.41....	1	1	.....	.....	IV
5318.92....	4	2	.....	.....	IV	5738.75....	1	1	tr	.....	III
5328.53....	50n	15	10	6	II	5746.64....	2	1	tr	.....	III
5329.33....	20n	10	6	3	II	5753.89....	2	.....	.....	.....	V
5329.95....	5n	4	2	1	II	5781.42....	8	5	3	tr	III
5340.65*...	4	?	.....	.....	IV?	5782.10....	8	5	3	tr	III
5345.00....	2	2	1	.....	III	5783.38....	20	10	5	1	III
5345.99....	70	40R	40	30	I	5784.17....	20	10	5	1	III
5348.50....	50	30R	30	20	I	5785.29....	20	8	4	1	III
5387.14....	5	2	tr	.....	IV	5785.95*...	15	6	4	1	III
5387.73*...	3	?	tr	.....	III	5786.19*...	?	10	10	5	I A
5390.60....	3	1	.....	.....	IV	5787.25....	3	3	2	.....	III
5391.56....	2	?	.....	.....	IV	5788.22....	40	12	8	2	III
5400.75....	8	3	1	.....	III	5788.59....	4	2	1	.....	III
5405.19....	3	?	.....	.....	IV	5791.30....	50	20	15	3	III
5410.01....	100	60R	60	40	I	5792.00....	1	1	tr	.....	III
5442.60....	3	?	.....	.....	IV	5838.88....	2	2	1	.....	III
5464.12....	4	?	.....	.....	IV	5844.84....	2	2	1	.....	III
5480.71....	4	2	.....	.....	IV	6330.30....	25	50	50	50	I A
5628.82....	8	4	2	.....	III	6363.03....	15	30	30	30	I A
5638.37....	1	1	tr	.....	III	6501.43....	2	15	10	10	I A
5642.59....	2	2	1	.....	III	6529.36....	2	.....	.....	.....	V
5648.40....	1	1	tr	.....	III	6538.12....	3	18	15	15	I A
5649.52....	2	2	tr	.....	IV	6573.10....	2	12	12	12	I A
5658.82....	1	1	tr	.....	III	6597.80....	2	.....	.....	.....	V
5664.24....	8	4	2	.....	III	6630.25....	4	20	20	20	I A
5681.42....	2n	.....	.....	.....	V	6661.30....	12	3	.....	.....	IV
5682.63....	4n	2	1	.....	III	6669.50....	3	1	.....	.....	IV
5694.94....	10	4	2	.....	III	6881.7.....	2	1	tr	.....	III
5698.53....	20	6	3	tr	III	6882.4.....	5	2	1	.....	III
5700.75....	1	1	tr	.....	III	6883.2.....	10	4	2	.....	III
5702.52....	10	5	2	.....	III	6924.4.....	10	5	2	.....	III
5712.87....	2	.....	.....	.....	V	6925.4.....	6	3	1	.....	III
5712.98....	6	7	3	tr	III	6978.75....	15	8	2	.....	III

REMARKS ON TABLE II

λ	
3578.81, 3593.64, 3605.49	Widely reversed at high temperature.
3603.89	Concealed at high temperature by λ 3605.49.
3903.05	Difficult blend with Class II Fe line.
3911.97, 3912.13	Measured by writer in vacuum arc. Blend into wide and diffuse line in arc in air.

λ	
4097.80	As for λ 3912.
4098.11	
4098.33	
4111.02	As for λ 3912.
4111.51	
4111.82	
4129.36	Measured by writer in vacuum arc.
4211.50	May be close double.
4255.70	Concealed at high temperature by λ 4254.51.
4459.92	Blend with strong V line in furnace.
4480.45	Double, scarcely resolved.
4490.8	Very diffuse in arc.
4527.53	Blend with strong Ti line in furnace.
4527.65	
4535.89	Blend with Ti.
4632.39	Disturbed by carbon.
4639.78	Disturbed by carbon.
4646.68	λ Rowland.
4656.38	Disturbed by carbon.
4681.10	Disturbed by carbon.
4695.35	Disturbed by carbon.
5110.93	Disturbed by carbon.
5113.30	
5144.85	Disturbed by carbon.
5161.94	
5340.65	Disturbed by carbon.
5387.73	
5785.95	λ Rowland.
5786.19	λ Rowland. Faint in arc, blended with λ 5785.95.

GENERAL CHARACTERISTICS OF THE VANADIUM AND CHROMIUM SPECTRA

1. *Low temperature lines of chromium.*—As has been noted, some chromium lines appeared at a temperature lower than that used for the low-temperature column of Table II. Table III is a list of these lines with their intensities estimated from a photograph taken with the 1-meter concave grating, a bathed film with filter being used so that the spectrum from λ 3500 into the red was registered. The temperature read 1728° C. and the prolonged exposure made it probable that the spectrum for this temperature was fairly complete. Almost all of the lines as far as λ 5000 were

obtained also on a plate taken at the same temperature with the 15-foot concave grating.

The intensities in Table III are quite different from those in the low-temperature column of Table II, given at 2000–2100°. This is probably in some measure due to differences in contrast and color-curve between the film and the plate, but chiefly to the fact that the lines of Class I retain a high relative intensity at the minimum temperature for their appearance, while those of Class II, which make up the remainder of Table III, are weaker than in Table II.

TABLE III

CHROMIUM LINES GIVEN BY A TEMPERATURE OF 1700–1800°

λ	I	λ	I	λ	I
3578.81	25	4344.68	40	5048.95	tr
3593.64	20	4351.22	20	5052.08	3
3605.49	20	4351.98	30	5068.45	1
3615.77	1	4359.82	40	5073.10	5
3730.96	3	4371.48	50	5092.03	1
3732.19	3	4373.42	10	5122.27	1
3883.48	8	4385.15	40	5123.63	2
3885.36	7	4391.93	8	5204.71	70
3886.92	7	4412.44	4	5206.24	80
3894.20	6	4497.03	60	5208.60	100
3903 {.05, .29}	10	4546.10	60	5247.72	50
		4565.70	25	5264.35	50
3908.91	10	4580.26	50	5265.90	30
3916.41	6	4591.61	35	5296.86	60
3919.32	12	4600.90	50	5298.46	60
3921.21	8	4613.53	40	5300.89	20
3928.82	8	4616.28	50	5328.53	1
3941.67	12	4626.35	50	5329.30	tr
4254.51	200	4646.35	60	5345.99	80
4275.00	175	4651.49	40	5348.50	70
4289.90	150	4652.38	50	5410.01	80
4337.74	30	4942.68	10	6330.30	12
4339.62	20	4965.10	6	6363.03	6
4339.90	20	5022.04	tr	6630.25	3

2. *Successive development of the classes.*—The low-temperature spectrum, described for chromium in the preceding section, occurs for each of the elements which have been studied with the furnace at a stage probably not more than 200° above the melting-point. The medium temperature (about 2300°) produces a rich spectrum. The Class II lines are well developed and the Class III lines are present. Those lacking are the weaker arc lines, some lines which

are strong but diffuse in the arc, and the enhanced lines. At the highest temperatures used the number is increased by the addition of the Class IV lines, and in the case of vanadium, as with titanium, by the faint appearance of some of the stronger enhanced lines. A striking change produced by the high temperature is the general widening of the lines present at lower temperature, together with an increase in the number of reversals.

3. *Changes with the wave-length.*—Photographs made with the 1-meter concave grating showed the spectra of vanadium and chromium extending farther into the ultra-violet as the temperature rises, a condition also observed for iron and titanium. The limits of the vanadium spectrum on these films are roughly λ 3200, λ 2800, and λ 2500 for the three temperatures. The arc spectrum extends to shorter wave-length. Aside from the extension toward shorter waves nothing definite appears in the way of a general change. Low-temperature lines occur in groups throughout the spectrum, beginning with the limit in the ultra-violet. At the red end, while a number of lines occur in each spectrum for which the furnace is more favorable than the arc, these are not relatively strong at low temperature, but are for the most part in Class III.

The tendency in all light-sources for lines of shorter wave-length to reverse more easily is perhaps nowhere so striking as in the furnace spectra. If reversal were dependent merely on the presence of rarer vapor at a lower temperature, lines in the red region should reverse as easily as in the violet, since a number of red lines are given by the low-temperature furnace. Reversal is, however, clearly a function of wave-length. The high-temperature furnace gives numerous and wide reversals of lines in the region of shorter wave-length, presumably by reason of the cooler vapor near the ends of the tube; but in the green reversal becomes more difficult and in the yellow and red even the strong low-temperature lines of these elements remain hard and sharp in the furnace spectrum.

4. *Absence of the band spectra.*—The arc spectra of vanadium and chromium each show a series of bands shaded toward the red. The heads of these have been measured[1] as approximately λλ 5470, 5737,

[1] Kayser, *Handbuch der Spectroscopie*, **5**, 376; **6**, 786.

6087, 6478 for vanadium, and λλ 5565, 5795, 6052, 6395 for chromium. These appear distinctly on my arc photographs but in none of the furnace spectra. The present evidence is that these bands are due to oxides formed in the arc and are not low-temperature spectra of the metals themselves.

5. *Comparison with the arc spectrum.*—In Tables I and II lines of intensity 1 in the arc are entered only when they occur also in the high-temperature furnace. The number of arc lines in Exner and Haschek's tables which are thus omitted from the furnace list is much greater for chromium than for vanadium. Of the stronger arc lines 35 chromium lines occur in Class V, while this class for vanadium is limited almost entirely to the enhanced lines (*V E*). In short, the relative behavior of the two elements is similar to that of titanium and iron, in that when the vanadium spectrum has once appeared (its high melting-point rendering the initial temperature higher than that of chromium), the furnace is highly efficient in producing a rich spectrum, giving at high temperature a spectrum closely comparable in number of lines with that of the arc.

The most interesting difference between the arc and furnace spectra is probably the large number of lines relatively much stronger in the furnace than in the arc and designated by *A* after the class number. It is difficult to reconcile the behavior of these lines with a continuous change in temperature alone between the arc and the furnace. It would appear that certain conditions needed for the emission of these lines are stronger in the furnace than in the arc. No discontinuity is apparent in the development of the spectrum from one furnace temperature to another. A line strong at low temperature is strong also at medium and high temperatures, but it may be a weak line in the arc, and the same is true for lines which develop at the successive temperature stages. A Class III line, for example, may show a normal increase from medium to high temperature and then drop to a low intensity in the arc. Further investigation may show that the emission of such lines is greatly localized in the arc and that the furnace is better suited to produce a vapor in the same condition as the given region of the arc, but at present the reason for the difference is obscure.

EXPLANATION OF THE PLATES

The two sections of Plate II show the vanadium spectrum from λ 4000 to λ 4950 for the arc and for three furnace temperatures. An interesting region in the red is reproduced in Plate III. The large changes in relative intensity of many lines are brought out, together with the maintenance of a high intensity at low temperature by the lines of Class I. The development of a typical carbon fluting is well shown in Plate II. The low temperature is barely able to produce the strong head at λ 4737.

Plate IV gives a similar series of arc and furnace spectra for chromium from λ 5100 to λ 5425. Most of the prominent lines here belong to Class I and the chief change in them is a widening at high temperature. Strong lines in other classes occur, however, at λλ 5197, 5225, 5255, and the groups at λλ 5276 and 5329. The growth of the strong carbon band λ 5165 is also shown in this plate.

SUMMARY

1. The electric furnace spectra of vanadium and chromium have been studied for the ranges λ 3150–λ 6850 and λ 3550–λ 7000, respectively, the classification of lines being based on a comparison of the spectra given by three furnace temperatures with reference to the temperature at which a line appears and its rate of strengthening with increase of temperature.

2. The leading features in the development of the vanadium and chromium spectra are similar to those observed for iron and titanium, the vanadium spectrum being very similar to the latter.

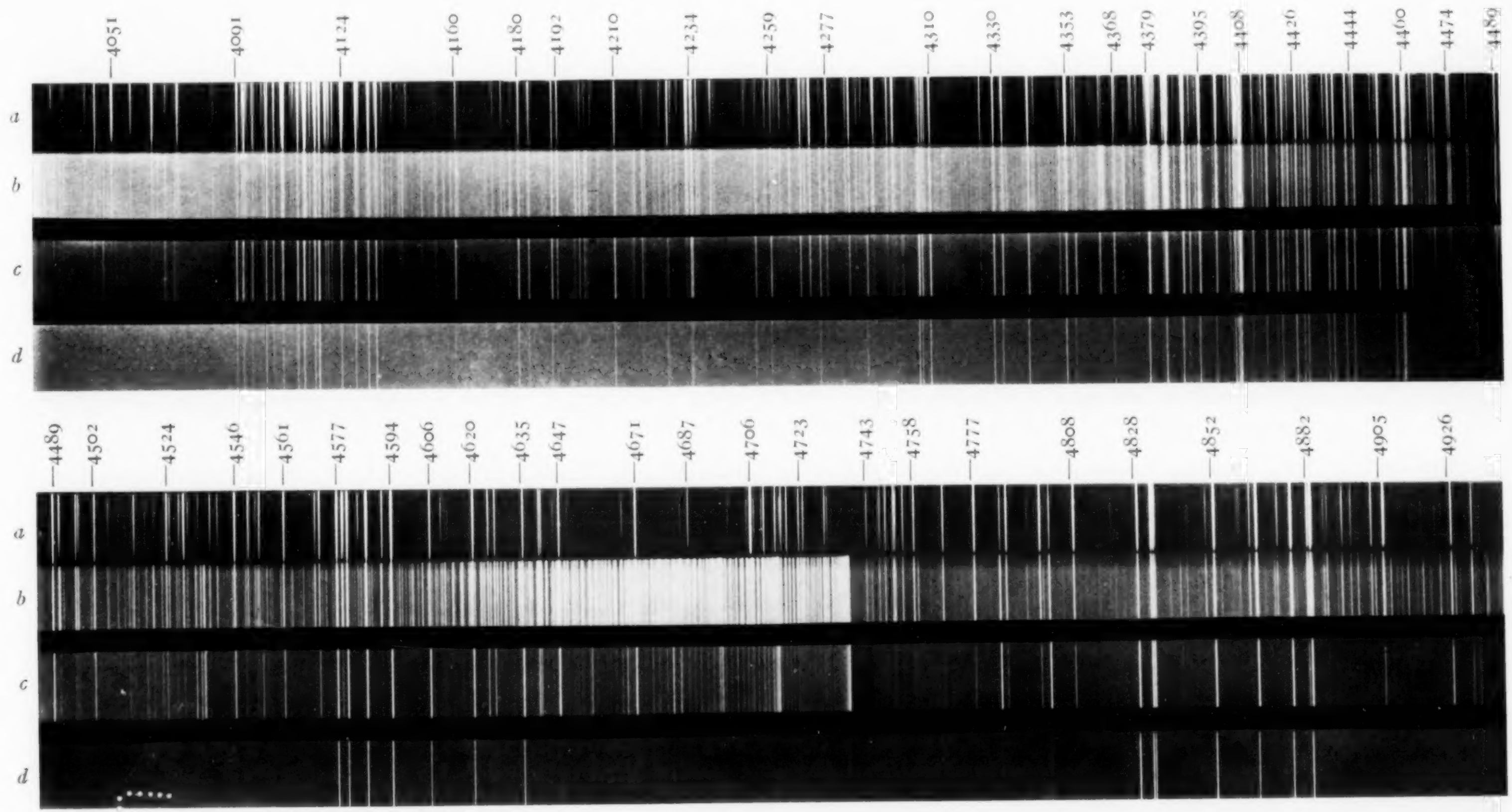
3. The chromium spectrum near the temperature at which the vapor begins to radiate shows a predominance of the lines of Class I, which change little at higher temperatures.

4. Certain chromium lines, very diffuse in the arc in air, may be resolved into sharp components in a vacuum source, either furnace or arc.

5. A large number of lines belonging to various furnace classes are relatively weak in the arc.

6. The extension of the spectrum into the ultra-violet increases as the temperature rises. In other respects the distribution of

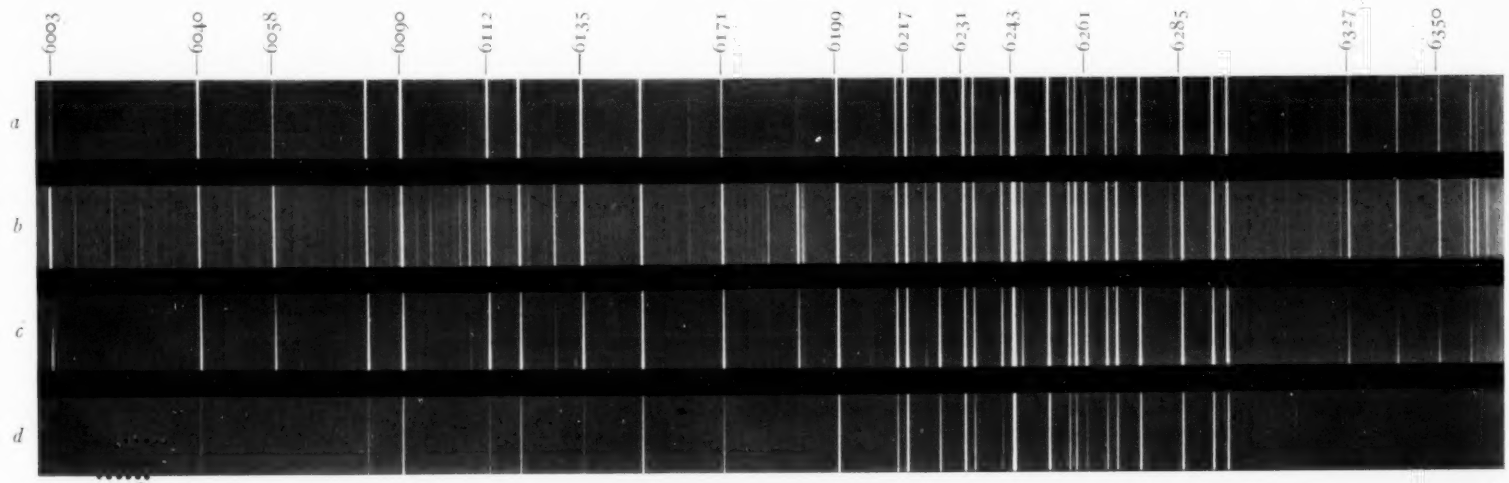
PLATE II



Furnace and Arc Spectra of Vanadium

a. Vanadium in carbon arc.
b. Spectrum of the electric furnace at 2600° C.
c. Spectrum of the electric furnace at 2350° C.
d. Spectrum of the electric furnace at 2100° C.

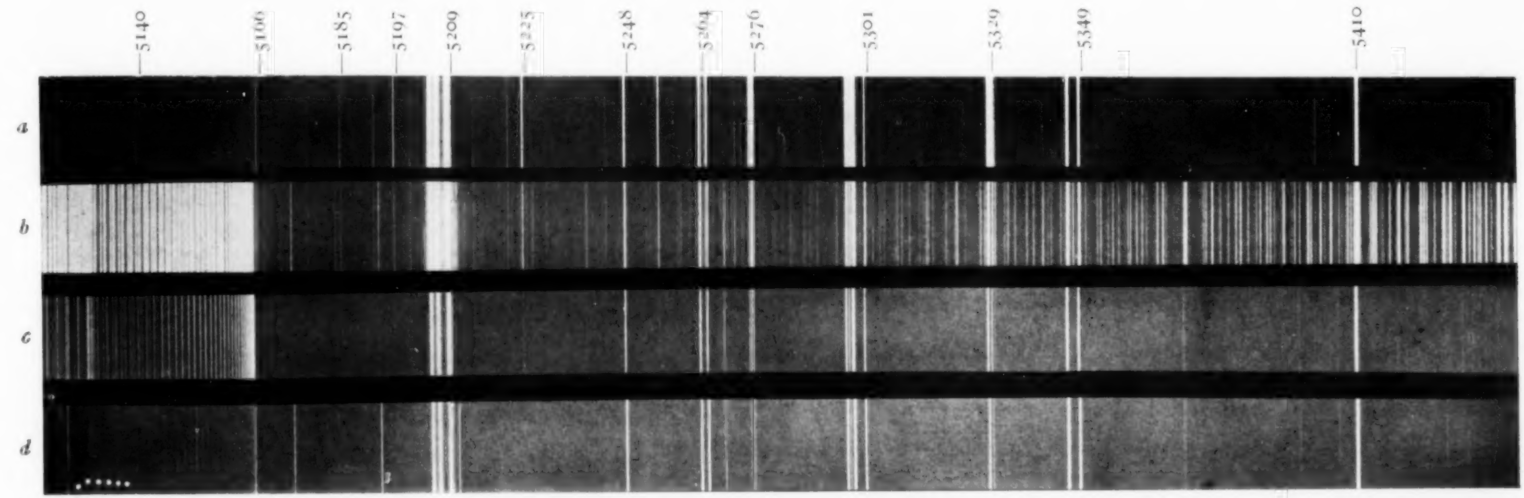
PLATE III



FURNACE AND ARC SPECTRA OF VANADIUM

a. Vanadium in carbon arc.
b. Spectrum of the electric furnace at 2600° C.
c. Spectrum of the electric furnace at 2350° C.
d. Spectrum of the electric furnace at 2150° C.

PLATE IV



FURNACE AND ARC SPECTRA OF CHROMIUM

a. Arc spectrum of chromium.
b. Spectrum of the electric furnace at 2600° C.
c. Spectrum of the electric furnace at 2350° C.
d. Spectrum of the electric furnace at 2100° C.

lines at different temperatures shows no definite relation to the wave-length.

7. The ability of lines to show self-reversal in the furnace distinctly increases with decreasing wave-length.

8. The absence from the furnace of the banded spectra which appear in the vanadium and chromium arcs indicates that they are probably due to oxides of the metals.

Mount Wilson Solar Observatory
November 1914

THE FLASH SPECTRUM WITHOUT AN ECLIPSE REGION λ 4800–λ 6600[1]

By WALTER S. ADAMS and CORA G. BURWELL

In a brief communication[2] published in 1909 Hale and Adams described the methods employed in photographing the chromospheric spectrum with the 60-foot tower telescope and the powerful spectrograph used in conjunction with it. Some results of the observations in two limited regions of the spectrum were given to indicate the character of the photographs obtained and the degree of accuracy of the measured wave-lengths. Observations made since that time by Mr. Hale with the 150-foot tower telescope have shown that the use of the larger solar image probably will lead to a distinct advance in the quality of the chromospheric photographs. In spite of this consideration, however, it has seemed desirable to publish the results already obtained, not only because they give some indication of the possibilities in the way of investigations of the chromospheric spectrum with the use of a solar image of moderate size, but also because the results almost certainly will differ to some extent from those obtained with the larger image on account of difference in the level of the observations. Since the slit is held rigorously tangent to the solar image during the exposures, it should be possible under the finest conditions of definition to reach a somewhat lower level in the chromosphere with the larger image.

The method employed in obtaining the photographs was that described in the communication by Hale and Adams already referred to. The light from the sun's limb falls upon a diagonal prism so placed as to reflect the light horizontally to a second prism immediately above the slit. The first prism is mounted upon a slide with a screw adjustment allowing of motion toward or away from the second prism. After the sun's image has been brought tangent to the slit the observer selects a bright line of the chromospheric spectrum and brings it into the field of view of an

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 95.

[2] *Mt. Wilson Contr.*, No. 41; *Astrophysical Journal*, **30**, 222, 1909.

eyepiece, mounted in an opening near the end of the plate-holder. During the exposure this line is maintained at maximum brightness by guiding with the screw controlling the position of the first diagonal prism, thus moving the sun's image slightly on the slit. The objective employed in the 60-foot tower telescope is corrected for visual light and hence is not well adapted for photography in the blue and violet portions of the spectrum. For this reason, and on account of the difficulty of seeing with sufficient distinctness in this region the bright lines necessary for guiding, only a very few photographs have been obtained to the violet of λ 4800.

The second order of the grating was used for all of the photographs, corresponding to a linear scale on the negatives of about 1 mm = 0.9 angstrom.

The exposure times varied from four minutes in the yellow and green region to eight minutes in the red.

Table I contains the results of the measures. The portion of the spectrum between λ 4800 and λ 5500 has been studied much more extensively than that to the red of λ 5500, and the wave-lengths given depend upon a laiger number of determinations. For lines of greater wave-length than λ 5900 only two measures are available.

The photographs upon which these results are based were taken largely to test the methods employed, and in the case of some of the earlier photographs the diagonal prisms used were too small to give the full length of the brightest and longest chromospheric lines. As a result we have not attempted to measure the lengths of the lines and use them as a basis for discussion of level in the solar atmosphere. It is evident, however, that with a slit of sufficient length to admit the longest lines, measures of the size of the arcs made in this way would have a marked advantage over those from eclipse photographs taken without a slit in that the exposure times would be uniform for lines of all lengths and not progressively longer as in eclipse spectra for the lines of greatest length. The photographs taken without an eclipse have, moreover, the advantage of accurate guiding.

The results given in Table I are for the most part self-explanatory. The measured wave-lengths of the bright lines are in the first column, and following these the lines in Rowland's

table with the corresponding elements and intensities. We have preferred not to add a large number of somewhat questionable identifications to those made by Rowland, but have included several taken mainly from Hasselberg's arc tables which sun-spot observations have verified. The chromospheric intensity given in the fifth column is on an arbitrary scale extending from 0, a line just visible on the continuous background, to 50, which is the intensity of D_3 on our photographs.

The abbreviations used in the last column are as follows:

dr = double reversal
w = wide
bf = bright fringes
E = enhanced line

The term "bright fringes" is used in the case of dark lines which show a faint bright line on either side, in general too weak for measurement. They are true double reversals but very faint. These lines, on which no measurements have been made, are indicated in the first column of the table by the absence of figures beyond the decimal point, these being given in the second column (from Rowland's table).

THE LEVEL OF THE OBSERVATIONS

There are three features in these results that indicate a very low level in the solar atmosphere for the point under observation.

1. Essentially all of the stronger lines are double reversals, similar in type to those of the hydrogen lines, but of course very much narrower. This is an indication of low level.

2. A large proportion of the bright lines are very faint absorption lines in the solar spectrum. St. John has shown clearly that in general the fainter the line the lower the level of the gas producing the absorption.

3. The carbon fluting with its head at λ 5165 is very strong. This fluting is known from visual observations to originate at a very low level in the solar atmosphere.

In view of these facts, quite apart from the obvious consideration that a slit tangent to a solar image 16.8 cm in diameter under good conditions of definition should reach a point very close to the

TABLE I

WAVE-LENGTHS AND INTENSITIES FOR CHROMOSPHERE LINES

Observed λ	Rowland			Chr. Int.	Remarks
	λ	Element	Intensity		
4802.888	.879	....	0000	1	
4804.220	.232	La	000	1	
4804.530	.706	Co?	0	0	dr
.892				0	
4805.301	.285	Ti	3	2	dr E
4805.605	.606	Ti	0	1	
4807.308	......	....	....	0	
4807.726	.725	Cr, V	000	1	
4807.	.900	Fe	1	.....	bf
4809.204	......	La	....	2	
4810.730	.724	Zn	3	1	
4811.532	.542	Nd	000	2	
4813.670	.661	Co	1	2	
4814.147	.166	....	000N	1	
4814.676	......	....	....	0	
4815.262	.239	....	0000	0	
4815.831	.820	....	0000	0	
4816.011	.013	....	0000	1	
4817.856	.988	Ni? Fe?	2	0	dr
4818.033				0	
4819.173	.205	....	0000	0	
4819.818	.830	Y	0000	0	
4820.514	.593	Ti	1	1	
4823.543	.697	Mn	5	1	dr
.856				0	
4824.230	.325	Fe, Cr	3	1	dr E
.484				0	
4825.664	.666	Ti	000	3	
4825.906	.907	....	000	0	
4827.917	......	....	....	0	
4828.729	......	....	....	1	
4831.710	......	....	....	0	
4832.466	.460	Nd	0000	1	
4834.548	.695	Fe	1	0	dr
.834				0	
4835.890	6.059	Fe	2	1	dr
6.217				1	
4836.310	.313	Ti	0000	0	
4836.935	7.044	Cr	00	0	dr
7.180				0	
4838.543	.699	....	2	2	dr
.957	.837	Fe, Ni	1	1	
4839.594	.734	Fe	3	0	dr
.869				0	
4840.197	.193	....	0000	0	
4840.431	.449	Co	2	1	
4840.925	1.074	Ti	3	0	dr
1.250				0	
4843.	.336	Fe	3	.....	bf
4844.401	.408	Mn	0000	1	w

Observed λ	Rowland			Chr. Int.	Remarks
	λ	Element	Intensity		
4846.766	......	....	....	0	
4848.121	.110	....	0000	0	
4848.282	.438	Cr	2	0	dr E
.729	.605	Ti	0000	0	
4849.242	.357	....	0	1	dr
.453				0	
4849.664	.845	Cr	00	0	dr
50.073				0	
4851.680	.689	Ca, V	1	1	w
4852.	.743	....	2	.....	bf
4854.584	.535	....	0000	0	
4855.030	.059	Fe, Y	1	4	
4855.	.600	Ni	3	.....	bf
4856.195	.203	Ti	1	0	
4857.	.579	Ni	1	.....	bf
4859.204	.221	Nd	000	1	
4859.803	.928	Fe	4	0	dr
60.050				0	
4861.092	.527	H, La	30	20	dr
.898				15	
4862.621	.783	....	0	0	dr
.923				0	
4864.356	.362	....	0000	0	
4864.484	.505	Cr	1	0	E
4864.906	.919	V	0	0	
4865.793	.798	....	1	0	
4866.331	.465	Ni	2	0	dr
.593				0	
4866.906	.930	....	0000	0	
4867.585	.724	....	00	0	dr
.847				0	
4868.048	.056	Co	1	2	
4868.252	.451	Ti	0	1	dr
.442				(2)	
.709				1	
4870.316	.323	Ti	1	1	
4870.982	.996	Ni, Cr	3	0	
4871.	.512	Fe	5	.....	bf
4872.	.332	Fe	4	.....	bf
4873.639	.630	Ni	2	0	
4874.189	.196	Ti	0	1	E
4874.368	.379	....	0000	0	
4874.689	.693	....	0000	1	w
4875.668	.671	V	1	1	
4876.	.586	Cr	1	.....	bf E
4878.169	.313	Ca	3	1	dr
.548	.407	Fe	4	1	
4881.750	.739	V	1N	1	
4882.	.336	Fe	3	.....	bf
4882.650	.670	Ce	000	1	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
4883.798	.867	Y	2	2	dr
.876				(4)	
.942				2	
4885.106	.264	Ti	2	0	dr
.421				1	
4885.	.620	Fe	3	.....	bf
4886.094	.132	Cr	00	0	
4887.182	.187	Ni, Cr	2	1	
4887.729	.715	....	0000	0	
4889.	.187	Fe?	3	.....	bf
	.294	Fe	2	.....	
4890.	.948	Fe	6	.....	bf
4891.	.683	Fe	8	.....	bf
4892.012	.047	Ti	000	1	
4893.	.030	Fe	1	.....	bf
4893.182	.228	Ti, Sc	000	0	
4893.987	.997	....	00	1	
4894.142	.141	Ce	0000	0	
4896.	.625	Fe	1	.....	bf
4900.102	.095	Ti, La	2	1	
4900.300	.301	Y	2	3	
4900.814	.808	....	000	0	w
4901.056	.152	Ti	0	0	dr
.270				0	
4902.248	.257	....	0000	0	
4903.	.502	Fe	5	.....	bf
4903.909	.896	....	0000	0	
4904.403	.597	....	3	0	dr
.761				0	
4905.143	.310	Fe?	0	0	dr
.487				0	
4908.032	.209	....	0N	0	dr
.325				0	
4908.628	.673	Co	000	0	
4909.439	.566	Fe	2	0	dr
.703				0	
4910.	.505	Fe	2	.....	bf
4910.965	.952	....	000N	0	
4911.387	.374	Ti	1	1	E
4912.226	.199	Ni	1	0	
4913.424	.450	....	0000	0	
4913.810	.803	Ti	2	1	
4914.175	.150	Ni	2	0	
4914.560	.583	Nd	0000	2	
4917.023	.028	....	0000	0	
4917.	.410	Fe	2	.....	bf
4918.536	.543	Ni, Ti	2	1	
4918.884	.886	Ni	0	1	
4919.019	.174	Fe	6	0	dr
.324				0	
4920.044	.047	....	00	2	
4920.220	.241	....	0000	0	

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
4920.552	.685	Fe	10	0	dr
.851				1	
4921.158	.147	La	0	3	
4921.982	.963	La, Ti	1	4	He?
4922.449	.446	Cr	2	0	
4923.544	.540	....	000d	0	
4924.012	.107	Fe	5	5	dr E
.189				4	
4924.	.956	Fe	3	.....	bf
4925.573	.746	Ni, V	1	0	dr
.876				1	
4926.034	......	....	....	0	
4928.	.050	Fe	2	.....	bf
4928.513	.511	Ti, Co	0	2	
4933.300	.514	Fe	2	0	dr
.711				0	
4934.152	.214	Ba-Fe?	3	1	dr
.381	.277		4	2	
4935.056	.048	....	0000	0	
4936.012	.015	Ni	2	1	
4936.546	.512	Cr	1	0	
4937.	.902	Ti	000	.....	bf
4938.471	.467	Ti?	000	1	
4938.708	......	....	....	0	
4939.243	.416	Fe	2	0	dr
.575				0	
4941.476	.496	Co, Sc	0000	0	
4941.763	.752	Ti	0000	0	
4942.548	.660	Cr	2	0	dr
.793				0	
4943.631	.623	Ce	0000	1	
4944.049	.087	Ce	0000	0	
4944.784	.751	Ce	000	1	
4946.	.568	Fe	3	.....	bf
4947.	.778	....	00	.....	bf
4950.150	.291	Fe	2	0	dr
.412				0	
4953.251	.392	Ni	2	0	dr
.536				0	
4954.878	.986	Cr	2	0	dr
5.116				0	
4955.528	......	....	....	0	
4957.	.785	Fe	8	.....	bf
4958.302	.431	Ti	00	1	dr
.542				0	
4959.282	.320	Nd	0000	1	
4961.100	.235	....	00	0	dr
.350				0	
4961.583	.564	....	0000	0	
4962.486	.467	Sr?	000	0	
4962.	.751	Fe	2	.....	bf

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
4965.235	.351	Ni	0	0	dr
.474				0	
4968.	.080	Fe	3	.....	bf
4969.966	0.098	Fe	3	0	dr
70.229				0	
4970.564	......	La	....	2	
4971.374	.531	Ni, Ce	1	0	dr
.661				1	
4973.146	.281	Ti-Fe	4	0	dr
.411				0	
4974.638	.642	....	0000	1	w
4975.491	.530	Ti	00	2	
4976.169	.314	Ni	0	0	dr
.633	.508	Ni	1	0	
4978.368	.372	Ti	00	1	
4978.	.785	Fe	3	.....	bf
4979.366	.391	....	000	0	
4980.132	.352	Ni-	4	0	dr
.588				0	
4981.462	.453	....	0000	0	
4981.773	.912	Ti	4	0	dr
2.049				0	
4984.	.297	Ni	2	.....	bf
4985.	.730	Fe	3	.....	bf
4986.290	.403	Fe	1	0	dr
.551				0	
4986.982	......	La	....	1	
4988.291	.313	....	000	1	
4989.010	.130	Fe	2	0	dr
.264	.325	Ti	00	1	
4990.106	.147	Nd	000	1	
4990.544	.625	Fe	0	0	dr
.739				0	
4991.115	.247	Ti	3	1	dr
.348				0	
4991.	.452	Fe, La	2	.....	bf
4993.533	.531	....	0	2	
4994.	.316	Fe	3	.....	bf
4995.220	.208	....	0000Nd?	0	
4997.148	.283	Ti	0	0	dr
.407				0	
4999.554	.689	Ti, La	3	1	dr
.815				0	
5001.166	.165	Ti	0	1	
5001.639	.654	....	000	0	
5002.	.044	Fe	5	.....	bf
5002.491	.510	V	0000	0	
5005.591	.581	....	000	1	
5005.	.896	Fe	4	.....	bf
5006.	.306	Fe	5	.....	bf
5007.285	.398	Ti	3	1	
.646	.461	Fe	2	1	

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5009.633	.829	Ti, Co	00	1	dr
10.001				1	
5011.927	......	Ce	....	1	
5012.108	.252	Fe	4	1	dr
.434	.335	....	1	1	
5012.	.625	Ni	1	.....	bf
5013.890	.871	Ti	0	1	
5013.967	.953	Ce	0000	0	
5014.250	.369	Ti	2	1	dr
.585	.457	Fe	3	0	
5016.216	.340	Ti	2	0	dr
.469				0	
5017.	.762	Ni	3	.....	bf
5018.519	.629	Fe	4	5	dr E
.727				4	
5019.740	......	....	....	0	
5020.050	.208	Ti	2	1	dr
.347				1	
5022.222	.414	Fe	3	0	dr
.574				0	
5023.	.052	Ti	2	.....	bf
5024.242	......	....	....	0	w
5024.900	5.027	Ti	3	0	dr
5.195				0	
5025.725	.749	Ti	1	0	
5025.950	.938	....	000	0	w
5027.	.305	Fe	3	.....	bf
5029.	.805	Fe	1	.....	bf
5030.103	.096	....	0000	1	w
5031.084	.058	Sc	0000	1	
5031.172	.199	....	3	3	
5032.244	.252	C	0000	1	w
5033.700	.714	....	000	1	w
5034.354	.354	C	000	0	
5034.568	.530	....	0000	0	
5034.982	......	....	....	0	
5035.	.542	Ni	5	.....	bf
5036.306	.332	....	0000	0	
5037.968	......	Ce	....	0	
5038.292	.579	Ti	2	1	dr
.890				0	
5039.	.428	Fe	3	.....	bf
5040.020	.138	Ti	3	1	dr
.275				1	
5040.602	.644	C	0000	1	w
5040.926	1.069	Fe	3d?	1	dr
1.380	.255	Fe	4	0	
5041.066	.795	Ca	2	1	dr
2.125	.936	Fe	4	2	
5042.	.367	Ni	1	.....	bf
5043.	.761	Ti	00	.....	bf

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5044.232 .533	.394	Ni, Co-Fe	3	1 0	dr
5045.451	.454	....	00	0	
5047.951	......	He?	....	0	
5048.464 .770	.612	Fe	3	0 0	dr
5050.	.008	Fe	6	.....	bf
5050.905	.919	C	000	0	
5051.558 .960	.683 .825	Ni Fe	1 4	1 1	dr
5052.352	.338	....	0N	0	w
5052.795	.803	....	00	0	
5053.038	.056	Ti	0	1	
5053.771	.756	....	00N	0	
5054.253	.261	Ti	000	0	
5056.290	.307	C	000	0	
5057.866	.875	....	0000	0	
5058.509 .809	.674	Fe	00	0 0	dr
5059.407	.409	....	000	0	
5060.096 .413	.258	Fe	3	1 1	dr
5061.899	.882	C	00	0	
5062.297	.285	Ti	0	2	
5063.353	.355	C	00	1	
5063.468	.479	C	000	1	
5063.909	.927	....	0000	0	
5064.244	.244	Ti	00	0	
5064.671 .974	.836	Ti	3	0 1	dr
5065.	.207 .380	Fe Fe	3 2	....	bf
5066.972	6.908 7.039	....	00 000	1	w
5068.573	......	....	....	0	
5068.800 9.099	.944	Fe	5	0 0	dr
5069.542	.592	Ti	000d	0	
5070.164	.165	....	00	0	
5071.954	.969	....	000N	1	
5072.029 .551	.257	Fe, C	3	1 1	dr
5072.	.849	Fe	2	.....	bf
5073.238	......	C	....	0	
5073.630	.637	Ti	00	1	w
5074.714 5.096	.932	Fe	5	0 0	dr
5075.509	.480	Ce	00	2	
5076.194 .731	.450	Fe, Ce	3	0 2	dr *
5077.690	......	Co	....	0	
5078.544	.541	C	000	0	
5078.883	.891	....	0000	1	
5079.003 .528	.158 .409	Fe Fe	3 4	0 1	dr
5079.	.921	Fe	4	.....	bf
5080.275	.288	C	0000	2	
5080.599 .843	.714	Ni	4	0 1	dr
5081.736	.764	Sc	000	2	
5081.943	.942	C	000	0	
5083.180	.205	C	000Nd?	1	
5083.383 .635	.518	Fe	4	0 0	dr
5083.896	.877	Sc	000	1	
5084.	.279	Ni	3	.....	bf
5084.849	.876	....	000	1	
5085.691	.668	Sc	0	0	
5086.394	.422	....	00	1	
5086.602	.570	C	000	1	
5087.096	.104	Sc	0000	0	
5087.592	.601	Y	1	4	
5088.202	.175	....	000	1	
5089.390	.387	....	000Nd?	1	w
5089.997	0.004	Sc, Nd	0000	0	
5090.810 1.100	.954	Fe	5	0 0	dr
5092.503	.483	C	00	1	
5092.984	.977	Nd	000	2	
5093.868	.858	C	0000N	0	
5095.332	.348	....	00d?	1	
5096.665	.660	....	0000	0	
5096.930	.908	C, Sc	000	1	
5098.309	.302	C	00N	1	
5098.480	.492	C	000N	0	
5098.	.885	Fe	3	.....	bf
5099.947	.957	....	000	1	
5100.821	.827	....	00	0	
5101.245	.251	C, Sc	000	0	
5101.652	.655	....	000	0	
5102.580	.599	....	000	0	w
5103.319	.297	C	0000	0	
5103.894	.909	C	000	1	
5104.089	.083	C	0000	0	
5105.371	.356	....	0000	0	
5105.571 .825	.718	Fe	4	0 0	dr
5106.525	.556	C	0000	0	
5106.776	.773	C	000	1	
5107.495 .905	.619 .823	Fe Fe	4 4	0 0	dr
5108.066	.056	C	000	1	

* Solar line double.

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5109.277	.291	C	000d?	1	
5109.	.827	Fe	2	.....	bf
5110.182	.188	C	0000	0	
5110.	.574	Fe	5d	.....	bf
5110.921	.938	Cr-C	00	0	
5111.429	.426	....	0000	0	
5111.806	.802	C	000	1	
5112.440	.458	....	000	4	
5113.244	.240	Cr-C	0	0	*
5113.596	.617	Ti	0	0	
5114.402	.431	C	000Nd	1	
5114.732	......	La	....	2	
5115.251 / .754	.566	Ni	2	0 / 0	dr
5116.014	.045	C	0000	0	
5116.837	.849	C, Sc	0000	1	
5117.050	.071	C	000	0	
5117.331	.334	Ce	0000	0	
5118.278	.241	C	0000	1	
5119.296	.292	C, Y	00	1	
5119.541	.555	C	000	0	
5119.815	.820	C	0000	0	
5120.556	.516	C	000	.....	
	.592	Ti	0	2	
5120.833	.802	C	000	0	
5121.586	.609	....	0000	0	
5122.459	.481	C	0000	0	
5122.596	.613	C	0000	0	
5122.962	.968	Co-C	000	0	
5123.163	.178	La	000	2	
5123.364	.390	Y	0	2	
5123.751 / 4.002	.899	Fe	3	0 / 0	dr
5124.209	.219	C	000	0	
5124.901	.939	C	0000	0	
5125.876	......	Co	....	0	
5126.212 / .520	.371	Fe-Co	2	0 / 0	dr
5127.382 / .698	.533	Fe, Ti	3	0 / 0	dr
5129.165	.336	Ti?	3	0	dr E
.701	.546	Ni	2	1	
5130.763	.757	C, Nd	000	5	
5131.779	.771	C	0000	2	
5132.512	.523	C, Nd	000	1	
5132.857	.843	C	00	2	
5133.655 / 4.008	.870	Fe	4	1 / 1	dr
5134.506	.505	C	0000	0	
5134.862	.849	C	0000	0	
5135.347	.355	Y	0000	0	
5135.835	.752	C,–	000	1	w
	.880	C,–	000		
5136.411	.443	....	000	0	
5136.614	.625	C	0000	1	
5136.851	.835	C	0000	0	
5136.985	.969	....	000	1	
5137.	.250	Ni, Cr	3	.....	bf E
5137.756	.753	C,–	000	1	
5138.260	.279	C	0000	0	
5138.496	.518	V	0000	0	
5138.645	.690	C	0000	0	
5139.	.427	Fe	4	.....	bf
5139.539 / .775	.644	Fe	4	0 / 1	dr
5140.092	.094	C	0000	0	
5140.566	.553	Ce	0000	0	
5141.389	.386	C,–	000	2	
5141.775 / 2.052	.918	Fe	3	1 / 1	dr
5142.288	.279	....	0000	0	
5142.	.693	Fe	4d?	.....	bf
5142.966	.958	Ni	2	1	
5143.	.111	Fe	3	.....	bf
5143.499	.511	C	000	0	
5143.748	.764	C	000	0	
5144.214	.203	....	0000	0	
5144.742	.758	C,–	000	0	
5144.852	.847	Cr, C	00	0	
5145.094	.098	C	0000	1	
5145.386	.403	C	0000	0	
5145.652	.636	Ti-C	0	0	
5146.304	.291	C,–	00	4	
5146.656	.659	Ni–	3	0	
5146.941	.945	Co-C	000d?	1	
5147.841	.871	C,–	000	1	
5147.983	.992	C,–	000	1	
5148.	.222	Fe	2	.....	bf
	.410	Fe	3	.....	
5149.209	......	C-Co	....	1	
5150.340	.363	....	00	0	
5150.844	.842	C	0000	2	w
5151.	.020	Fe	4	.....	bf
5151.657	.628	C	0000N	0	
5151.953 / 2.229	2.087	Fe	3	0 / 0	dr
5153.335	.337	C	0000	1	
5153.442	.414	Fe-C	1	0	
5154.171 / .346	.244	Ti-Co	2	0 / 0	dr E
5154.552	.579	C	000	2	w
5155.050	.028	C	0000	0	

* Blend.

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5155.701	.694	C,–	000	1	
5155.945	.935	Ni	2	0	
5156.518	.530	Co	000	0	
5156.728	.728	C	0000	1	
5156.927	......	La	....	1	
5157.779	.783	C	000	1	
5157.944	.915	C	000	1	
5158.	.152	Ni	00	.....	bf
5158.702	.701	C	000	2	
5159.072	.026	Co-C	0000N	1	
5159.627	.634	C	000	1	
5159.937	.946	....	0000	1	
5160.730	.419	C,–	00N	1	
5160.569	.554	C	0000	0	
5161.199	.194	C	000	1	
5161.362	.353	C	000	1	
5161.907	.910	C	000	1	
5162.161	.153	C?	0000	0	
5162.	.449	Fe, C	5	.....	bf
5162.716	.690	C	0000	1	
5163.064	.074	Ti, C	000	0	
5163.573	.585	C,–	000	0	
5163.769	.756	C, La	000	0	
5164.004	.007	C	0000	0	
5164.163	.172	C	0000	0	
5164.395	.404	C,–	000	1	
5164.564	.562	....	0000	0	
5164.942	.950	C	0000	0	
5165.201	.209	C	0000	2	
5165.290	.297	C	0000	1	
5165.436	.416	C	0000	0	
5166.320 .578	.454	Cr-Fe	3	0 0	dr
5167.364	.497	Mg	15	2	dr
.780	.678	Fe	5	1	
5169.	.069	Fe	3	.....	bf
5169.149 .328	.220	Fe	4	5 8	dr E
5170.970	.937	Fe	0	0	
5171.659 .925	.778	Fe	6	0 0	dr
5172.706 3.004	.856	Mg	20	5 4	dr
5173.782 4.056	.917	Ti	2	0 2	dr
5175.528 .659	.575	....	000	0 0	dr
5176.330	.305	Co	000	0	
5176.475 .939	.735	Ni	1	0 0	dr
5178.421	......	....	....	0	
5178.682	.644	V	000	0	

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5179.948	.958	Nd	000	2	
5180.066 .388	.233	Fe	1	0 0	dr
5180.746	.747	....	000	0	
5181.351	.334	....	000	0	
5182.754	.761	....	0000	0	
5183.604 .935	.791	Mg	30	6 5	dr
5184.356	.445	Fe	2	0	dr
.718	.738	Fe, Ni	1	1	
5185.962 6.218	6.073	Ti	2	0 0	dr E
5187.624	.620	Ce	000	2	
5188.753 .903	.863	Ti	2	2 1	dr E
5189.726	.744	....	000	0	
5191.537 .761	.629	Fe, Ce	4	1 2	dr
5192.160	.155	Cr	00	1	
5192.784	.785	Nd	000	2	
5193.025 .255	.139	Ti	2	0 0	dr
5193.657	.669	Cr	000	0	
5194.018	.027	....	0000	0	
5196.120 .340	.227	Fe	1	1 0	dr
5196.630	.613	Cr	0	0	
5197.735	.743	....	2	9	
5198.769 9.002	.888	Fe	3	0 0	dr
5200.320	.355	Cr	00	0	
5200.577	.590	V, Y	0	3	
5201.259	.260	Ti	000	1	
5202.314	.439	Fe?	2	1	dr
.626	.516	Fe	4	1	
5203.126	.118	....	0000	0	
5204.564	.680	Cr	5	1	dr
.875	.768	Fe	3	1	
5205.887	.897	Y	0	5	bf
5206.	.215	Cr-Ti	5	0	
5206.739	.712	V	000	0	
5207.650 .985	.791	....	000N	0 0	dr
5208.028 .218	.111	Ti	00	1 0	dr
5208.483	.596	Cr	5	1	dr
.933	.776	Fe	2	0	
5210.196	.204	Co	0000	1	
5210.433 .687	.555	Ti	3	0 0	dr
5211.006	.015	....	000	0	
5211.699	.700	Fe	00	0	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5212.497	.503	Ti, Nd	0000	2	
5212.854	.859	Co	000Nd?	2	
5213.156	.155	....	0000	0	
5214.292	.286	Cr	00	1	
5215.	.353	Fe	3	.....	bf
5216.	.437	Fe	3	.....	bf
5217.	.552	Fe	3	.....	bf
5218.328	.369	Fe	1	0	
5219.201	.186	....	0000	1	
5220.289	.250	....	000	2	
	.358	Ni	0		
5221.058	.078	....	000	0	
5221.	.928	Cr	0	.....	bf
5222.	.556	Cr	00	.....	bf
5222.846	.849	Ti, Cr	00	1	
5223.789	.791	Ti	000	1	
5224.246	.239	Cr	000N	0	
5224.693	.712	Ti, Cr	00	1	
5225.154	.101	Cr	0	1	
	.198	Cr, Ti,	00		
5225.546	.695	Fe	2	0	dr
.833				0	
5226.610	.707	Ti	2	4	dr E
.785				3	
5227.	.362	Fe	5d?	.....	bf
5228.258	.268	Cr	000	0	
5228.405	.546	....	1	0	dr
.702				0	
5230.	.030	Fe	4	.....	bf
5230.195	.382	Co, Cr	00	0	dr
.554				0	
5231.144	.151	....	0000	0	
5232.676	.681	....	000	0	
5233.	.122	Fe	7	.....	bf
5234.216	.255	....	0000	0	
5234.374	.380	V, Nd	000	1	
5234.788	.791	....	2	8	dr?
5235.459	.557	Fe	1	0	dr
.838	.672	Ni	00	0	
5237.240	.254	Ce	0000	1	
5237.488	.493	Cr	1	2	E
5238.644	.742	Ti	000N	0	dr
.892				0	
5239.975	.992	Sc	1	3	
5240.637	.639	....	000	0	
5241.028	.040	V	000	1	
5241.944	......	Ce	....	0	
5242.517	.658	Fe	2	0	dr
.804				0	
5243.514	.526	Cr	00	0	
5243.	.946	Fe	1	.....	bf
5245.095	.118	....	0000	0	

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5246.320	.310	....	0000	0	
5246.972	.946	....	000	1	
5247.461	.466	Ti	000	1	
5247.	.737	Cr	2	.....	bf
5249.747	.751	Nd	0000	4	
5250.178	.193	Co	0000	1	
5250.241	.385	Fe	2	0	dr
.508				0	
5250.667	.817	Fe	3	0	dr
.968				1	
5252.832	......	Ce	....	0	
5253.	.633	Fe	2	.....	bf
5254.822	.830	Co	0000	1	
5255.028	.121	Fe	3	0	dr
.280	.295	Cr	0	1	
5255.674	.687	Nd	0000	4	
5255.996	.973	Ti	0000	0	
5257.104	.100	Sr	00	2	
5257.760	.814	Co	0	1	
5259.900	.912	Ce	0000	2	
5260.113	.142	Ti	000	0	
5260.438	.561	Ca	0	0	dr
.673				0	
5261.750	.876	Ca-Cr	3	0	dr
.979				0	
5262.293	.321	Ti	1	1	
5262.	.419	Ca	3	.....	bf
5263.	.486	Fe	4	.....	bf
5264.055	.038	Fe	0	0	
5264.195	.329	Cr	4	0	dr
.527	.415	Ca	3	0	
5264.974	.976	....	0	4	
5265.321	.321	Cr	00	0	
5265.570	.729	Ca	3	0	dr
6.011	.893	Ni-Cr	2	0	
5266.459	.482	Co	000	1	
5266.622	.738	Fe	6	0	dr
.844				0	
5267.284	.447	....	00	0	dr
.568				0	
5268.515	.515	Ni	0	0	
5268.665	.670	....	000	0	
5268.713	.784	Co	00	1	dr
.834				1	
5269.115	.125	....	000	0	
5269.602	.723	Fe	8d?	2	dr
.838				1	
5270.293	.438	Ca	3	0	dr
.664	.558	Fe	4	0	
5271.206	.228	....	00	0	
5272.198	.171	Cr	00	0	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5273.200	.339	Fe	3	0	dr
.638	.558	Fe-Cr	2	1	
5274.407	.408	Ce	00	3	
5275.141	.148	....	0	0	
5275.340	.340	Cr	00	1	
5275.	.454	....	1	.....	bf
5276.149	.169	Fe?	3	10	
5276.384	.344	Co	000	0	
5277.040	.047	Nd	000	1	
5280.054	.048	....	0	0	
5280.256	.239	....	00	0	
5280.803	.799	Co	00	2	
5281.647	.681	....	000N	0	
5281.858	.971	Fe	5	0	dr
2.121				0	
5283.649	.802	Fe	6	0	dr
.929				0	
5284.281	.281	....	1	6	
5287.349	.351	Cr	000	0	
5287.713	.741	Co	0000N	0	
5287.958	.958	Co	000	0	
5288.554	.705	Fe	2	0	dr
.805				0	
5289.976	.988	Y	000	0	
5291.006	0.984	La	000	0	
5292.365	.388	....	000N	0	
5292.803	.762	Fe	0	0	
5293.071	.044	....	000	0	
5293.334	.341	Nd	00	3	
5293.550	.543	....	000	0	
5296.	.872	Cr	3	.....	bf
5297.399	.407	Cr, Ti	000	0	
5298.334	.455	Cr	4	0	dr
.574				0	
5300.150	.152	Ti	00	0	
5300.784	.929	Cr	2	0	dr
1.062				1	
5302.145	......	Sc, La	....	2	w
5302.	.480	Fe	5	.....	bf
5302.818	.829	....	000	0	
5303.364	.401	Ce	0	0	
5303.718	.738	La	000	2	
5306.035	.040	....	0	1	
5306.640	.665	....	000	1	
5307.405	.541	Fe	3	0	dr
.648				0	
5308.594	.599	Ce	0	1	
5310.392	.417	Co	000	0	
5310.882	.866	....	0	0	
5311.634	.650	Nd	000	1	
5311.953	.962	....	000	0	
5312.838	.835	Co	00	1	
5313.042	.031	Cr	0	0	
5313.768	.758	....	1	1	
5316.735	.790	Fe	4	8	dr E
.842				8	
5316.965	.958	Co-	2	6	
5318.537	.534	Sc	00N	1	
5318.975	.955	Cr, Fe	0	0	
5319.276	.392	....	000	0	dr
.660	.502	....	000	0	
5320.005	9.999	Nd	00	3	
5320.	.220	Fe	0	.....	bf
5321.	.293	Fe	2	.....	bf
5322.964	.994	....	000	2	
5325.468	.460	Co	00	1	
5325.745	.738	....	2	3	
5326.144	.139	Co	000N	0	
5328.123	.236	Fe	8d?	1	dr
.367				1	
5328.	.722	Fe	4	.....	bf
5330.744	.748	Ce	000	2	
5332.727	.849	Co, Fe	1	0	dr
3.222	.089	Fe	4	0	
5333.849	.832	Co	000	1	
5334.391	.403	Sc	000	0	
5335.033	.050	Co	1	1	
5336.361	.356	Co	000	0	
5336.698	.660	Nd	0000	0	
5336.922	.974	Ti,-	4	3	w E
5337.517	......	Co	....	0	
5337.897	.910	Ce	0	2	
5339.708	.719	Co	000	0	
5340.	.121	Fe	6	.....	bf
5340.651	.639	Cr	0	0	
5341.	.213	Fe	7	.....	bf
5341.490	.514	Co	00	1	
5341.	.670	Ti	000	.....	bf
5342.892	.890	Co	1	3	
5343.552	.570	Co	0	1	
5343.	.622	Fe	2	.....	bf
5344.770	.767	Co	000N	0	
5345.	.991	Cr	5	.....	bf
5347.687	.712	Co	00	0	
5348.	.511	Cr	4	.....	bf
5349.286	.283	Co	000	0	
5349.506	.653	Ca	4	0	dr
.792				0	
5350.052	.059	Mn	00	0	
5350.283	.281	....	00	1	
5350.537	.547	....	00	2	
5351.253	.261	Ti	00	0	
5352.237	.234	Co	1	2	
5352.625	.591	....	000	0	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5353.703	.702	Co	0	6	
5356.291	.270	Sc	000	0	
5357.160	.178	Nd	000	1	
5358.167	.306	....	00	0	dr
.460				0	
5359.098	.127	Co	000N	0	
5359.386	.389	Co	00	1	
5359.695	.714	....	000	0	
5361.666	.697	Nd	000	4	
5363.052	.058	Co–	3	8	
5366.947	.950	Co	000	0	
5368.729	.741	....	000	0	
5369.100	.125	Co	0000	0	
5370.540	.522	Cr	00N	0	
5371.534	.656	Cr?	4	2	dr
.794	.734	Fe	3	1	
5372.120	.121	Nd	000	3	
5373.800	.905	Fe, Cr	2	0	dr
4.033				0	
5375.558	.516	Sc	000	0	
5377.	.028	Fe	0	.....	bf
5377.798	.800	Mn	2N	1	E
5379.652	.775	Fe	3	0	dr
.883				0	
5380.	.516	....	0N	.....	bf
5381.152	.221	Ti, La	2	2	E
5381.468	.514	Co	0000	1	
5381.955	.980	Co	000	1	
5383.201	.209	....	000	0	
5386.092	.089	Nd	000	1	
5386.977	.989	Ce	0000	1	
5387.778	.769	Cr	00	0	
5390.194	.203	Ti	000	0	
5390.600	.573	Cr	000	0	w
5391.535	.660	Fe	2	1	dr
.921	.820	Fe	1	1	
5393.573	.584	Ce	000	3	
5394.	.876	Mn	2	.....	bf
5395.317	.422	....	0	0	dr
.555				0	
5396.453	.448	....	00	0	
5397.229	.344	Fe	7d?	1	dr
.459				1	
5399.694	.675	Mn	1Nd?	0	
5400.802	.831	Cr	0N	0	
5402.158	.151	V	0000	1	
5402.686	.....	....	....	0	
5402.989	.982	Y	0	2	
5405.190	.192	Cr	00	0	
5405.	.554	....	1	.....	bf
5405.874	.989	Fe	6	0	dr
6.102				0	
5406.391	.388	....	0000N	0	
5407.413	.587	Mn	0	1	dr
.824	.688		0	1	
5409.253	.339	Fe, Ce	2	0	dr?
.444				2	
5409.833	.823	Ti	000	1	
5410.	.000	Cr	4	.....	bf
5411.448	.428	Ni	1	1	w
5411.774	.764	....	0000	0	
5412.868	.997	Mn	00	0	dr
3.152				0	
5413.889	.889	Mn	00N	0	w
5414.295	.279	Ce	00	3	
5415.	.416	Fe-V	5	.....	bf
5416.618	.587	Nd	0000	1	
5417.135	.247	Fe	0	0	dr
.362				0	
5418.211	.....	....	....	0	
5418.972	.979	Ti	1	2	w E
5420.369	.510	Mn	0N	1	dr
.756	.613		0N	1	
5421.176	.134	....	00	1	
5421.780	.783	Nd	0000N	1	w
5424.764	.860	Ni	1	0	dr
.982				0	
5425.473	.464	....	1	4	
5428.704	.....	....	....	0	
5429.362	.349	Ti	00	2	
5429.	.717	....	1	.....	bf
5429.802	.911	Fe	6d?	1	dr
30.012				1	
5430.	.062	....	0	.....	bf
5431.720	.747	Nd	000	1	w
5432.608	.753	Mn	1Nd?	1	dr
.924				1	
5433.195	.160	Fe	2	1	
5434.637	.740	Fe	5	0	dr
.855				0	
5444.796	.796	Co	00	3	
5446.425	.436	Sc	0000	0	
5446.643	.797	Ti	2	0	dr
.996				1	
7.245	7.130	Fe	6d?	0	
5447.726	.737	....	000	0	
5448.411	.582	....	00	0	dr
.609				0	
5449.427	.....	Ce, Nd	....	0	
5451.317	.330	Ce, Nd	000	1	
5452.	.309	....	00	.....	bf
5454.313	.326	....	000	0	
5454.776	.783	Co	00	2	
5455.	.834	Fe	4	.....	bf

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5457.	.670	Mn	00	.....	bf
5460.558	.721	Ti	00	0	dr
.897				0	
5462.	.705	Ni	1	.....	bf
5464.390	.490	Fe	0	0	dr
.602				0	
5466.472	.609	Fe	3	0	dr
.779				0	
5468.578	.601	Ce	000Nd?	2	
5470.634	.802	Mn	0	1	dr
1.018	.883		0	1	
5472.499	.503	Ce	000	2	
5473.581	.594	Ce	000	1	
5473.955	4.113	Fe	3	0	dr
4.278				0	
5474.278	.436	Ti?	00	0	dr
.628				0	
5476.981	7.123	Ni	5	0	dr
7.248				0	
5477.929	.901	Ti	00	0	
5478.558	.578	....	00	0	
5480.916	1.071	Fe	1	0	dr
1.235				0	
5481.	.652	Fe, Ti	1	.....	bf
5481.925	2.078	Ti, Sc	00	0	dr
2.186				0	
5483.	.307	Fe	1	.....	bf
5484.826	.846	Sc	000	0	
5485.229	.266	Nd	0000	0	
5485.901	.915	Nd	0000	2	
5487.	.354	Fe	1	.....	bf
5487.799	.959	Fe	3	0	dr
8.107				1	
5488.396	.374	V-Ti	00Nd?	0	
5489.879	.893	Co	000	2	w
5490.	.367	Ti	0	.....	bf
5490.892	.905	....	0	2	
5491.890	.897	....	0000	0	w
5493.092	.095	....	00	1	
5493.584	.709	Fe	1	0	dr
.814				0	
5494.223	.193	Nd	0000	0	
5497.607	.735	Fe	5	1	dr
.842				0	
5498.107	.105	....	000	0	
5498.931	.955	....	0000	0	
5501.546	.683	Fe	5	0	dr
.807				0	
5503.136	.286	Fe	1	0	dr
.433				1	
5504.111	.117	Ti, La	0	2	
5505.950	6.095	Mn	1	0	dr
6.221				0	
5506.697	.719	....	000	0	
5507.	.000	Fe	5	.....	bf
5507.974	.985	V	000	0	
5508.852	.840	....	0	0	
5510.096	.120	Y	0	3	
5510.832	.829	....	00	0	w
5510.946	.942	....	00	0	
5511.653	.644	....	000	0	
5512.280	.266	Ce	00	3	
5513.005	.198	Ca	4	0	dr
.360				0	
5513.780	.769	....	0000	0	
5514.427	.563	Ti	2	0	dr
.890	.753	Ti	2	0	
5516.803	.950	Mn	0	0	dr
7.137	.034	Mn	0	0	
5519.605	.633	....	000	0	
5520.712	.727	Sc	00N	0	
5521.770	.799	Y	00	1	
5522.483	.665	Fe	2	0	dr
.828				0	
5523.810	.783	....	000N	0	
5524.686	.684	....	000	0	
5525.332	.347	Co	00	1	
5525.	.765	Fe	2	.....	bf
5526.427	.405	....	000N	0	
5526.976	7.033	Sc	3	2	dr
7.108				2	
5527.776	.796	Y	000d	0	
5528.092	.084	....	0000N	0	
5528.	.641	Mg	8	.....	bf
5530.892	.997	Ti	00N	0	dr
1.109				0	
5532.336	.353	....	000	0	
5532.794	.968	....	1	0	dr
3.239	.092	....	0	0	
5534.061	.011	Nd	000d	0	
5534.527	.504	....	000	0	
5535.058	.061	....	2	7	
5535.424	.644	Fe	2	0	dr
.830				0	
5536.304	.300	....	000	0	
5536.518	.492	....	000	0	
5537.824	.928	Mn	00	0	dr
8.098	.025	Mn	00	0	
5540.210	.192	....	0000	0	
5543.980	4.157	Fe	2	0	dr
4.324				0	
5544.834	.831	Y	000	2	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5546.164	.147	....	000	1	w
5546.	.732	Fe	2	.....	bf
5547.108	.215	Fe, V	1	0	dr
.323				0	
5549.990	....	....	....	0	
5553.308	.346	....	000N	0	
5557.137	.196	Ce	000	0	dr
.407	.287		000	0	
5558.137	.136	....	0	0	
5559.080	.068	V	00Nd?	0	
5560.278	.434	Fe	2	0	dr
.563				0	
5560.896	.911	....	0000	0	
5562.773	.933	Fe	2	0	dr
3.094				0	
5563.674	.824	Fe	3	0	dr
.984				0	
5565.709	.700	Ti	00	1	
5565.	.931	Fe	3	.....	bf
5567.337	.367	....	0000N	0	
5567.488	.621	Fe	2	0	dr
.732				0	
5569.249	.249	....	0000	0	
5569.662	.848	Fe	6	0	dr
.968				0	
5576.	.320	Fe	4	.....	bf
5578.746	.946	Ni	1	0	dr
9.106				0	
5580.663	.672	....	000	0	
5882.063	.198	Ca	4	1	dr
.324				1	
5583.174	.186	....	000	0	
5584.700	.729	V	000	0	
5584.	.988	Fe	0	.....	bf
5585.396	.397	....	000	0	
5586.886	.991	Fe	7	1	dr
7.094				0	
5587.727	.800	Fe	0	0	dr
889				0	
5588.836	.985	Ca	6	1	dr
9.122				1	
5589.431	.582	Ni	0	0	dr
.768				0	
5590.222	.343	Ca	3	1	dr
.465				1	
5591.024	.039	Ti	000	0	
5591.574	.586	Sc	000	0	
5592.378	.375	Ni	0	1	
5592.	.487	Fe, Ni	1	.....	bf
5593.858	.961	Ni	0	0	dr
4.078				0	
5594.	.691	Ca	4	.....	bf
5595.914	.906	....	0000	0	
5598.358	.524	Fe	1	0	dr
.845	.711	Ca	4	1	
5599.533	....	....	....	0	
5601.348	.505	Ca	3	0	dr
.628				0	
5602.923	.995	Fe	1	1	dr
	3.083	Ca	3		
3.305	.186	Fe	4	1	
5603.867	.993	....	00	0	dr
4.131				0	
5606.108	.122	....	000	0	
5607.	.887	....	00	.....	bf
5608.386	.393	....	000	0	
5610.461	.467	Ce	000	1	
5612.556	.573	....	000	0	
5613.904	.929	Ce	000N	0	
5614.992	.997	Ni, Ce	0	0	
5618.144	.130	....	000	0	
5618.712	.858	Fe	1	0	dr
9.016				0	
5619.669	.824	....	0	0	dr
.931				0	
5620.506	.715	Fe	0	0	dr
.850				0	
5621.422	.438	....	000N	0	
5622.970	.996	....	000	0	
5624.116	.245	Fe	1	0	dr
.373				0	
5625.102	.096	V	000	0	
5625.745	.755	....	000	0	
5627.006	.034	....	000	0	
5627.718	.723	....	000	1	
5628.190	.239	....	000N	0	
5633.351	......	Ce	....	0	
5633.994	4.171	Fe	3	0	dr
4.330				0	
5636.	.045	Fe	1	.....	bf
5638.365	.488	Fe	3	0	dr
.646				0	
5641.	.206	....	1	.....	bf
5641.551	.667	Fe	2	0	dr
.791				0	
5642.	.112	Ni	0	.....	bf
5644.348	.365	Ti	0	2	
5645.	.830	Si	1	.....	bf
5646.810	.904	....	00	0	dr
.990				0	
5648.792	.796	Ti	00	1	
5649.652	.611	Cr	00N	0	w
5649.	.898	Fe-Ni	0d	.....	bf

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5651.532	.691	Fe	0	0	dr
.817				0	
5652.440	.542	Fe	1	0	dr
.640				0	
5653.934	4.091	Fe	1	0	dr
4.268				0	
5655.562	.715	Fe	2	0	dr
.884				0	
5658.106	.097	Y, Sc	2	1	w
5658.578	.561	Sc	0	3	
5658.643	.753	Fe	1	0	dr
	.884	Cr	0		
9.170	.052	Fe	4	0	
5661.402	.418	....	0000	0	
5662.344	.374	Ti	0	1	
5663.134	.155	Ti, Fe, Y	1	3	
5664.	.218	Ni-Cr	1N	.....	bf
5664.770	.797	....	000	0	
5665.632	.775	Si	1N	1	dr
.884				0	
5667.364	.368	Sc	0	2	
5667.634	.739	Fe	2	0	dr
.855				0	
5668.586	.593	V	000	0	
5669.136	.130	Ce, Nd	0000	1	
5670.154	.163	Ni, Ce	0	0	
5671.066	.071	V	0	1	
5671.715	.712	....	00N	0	
5672.039	.047	Sc	0	1	
5677.732	.919	Ce	00	0	dr
8.095				0	
5679.	.249	Fe	3	.....	bf
5682.695	.869	Na	5	1	dr
3.026				1	
5684.415	.415	Sc	1	2	
5687.056	.063	Sc	000	1	
5687.	.697	....	0	.....	bf
5688.267	.436	Na	6	1	dr
.619				1	
5688.736	.759	Nd	0000	3	
5689.694	.694	Ti	0	1	
5690.251	.286	....	0000	0	
5690.484	.646	Si	3	0	dr
.770				0	
5693.669	.865	Fe	3	0	dr
4.056				0	
5694.959	.962	Cr	0	1	
5695.180	.207	Ni	2	0	
5696.905	.869	....	0000N	0	
5698.051	.047	....	0000Nd?	0	
5698.	.242	Fe	0	.....	bf
5698.	.555	Fe, Cr	1	.....	bf
5698.754	.746	V	1	2	
5700.356	.402	Sc	00	0	
5701.	.323	Si	1N	.....	bf
5702.455	.543	Cr	0	0	dr
.676				0	
5702.857	.876	Ti	000	1	
5703.580	.591	....	0000	0	
5703.785	.797	V	1	1	
5705.969	6.215	Fe, Nd	3	0	dr
6.424				1	
5707.202	.204	V	0	0	
5708.470	.622	Si, Nd	3N	1	dr
.769				0	
5709.472	.601	Fe	5	0	dr
.947	.775	Ni	5	0	
5711.123	.313	Mg	6	0	dr
.462				0	
5712.	.098	Fe	3	.....	bf
5712.	.357	Fe	2	.....	bf
5714.102	.120	Ti	000	1	
5714.	.380	Fe	0	.....	bf
5715.473	.....	Ce	....	1	
5716.653	.671	Ti	00	0	
5718.	.055	Fe	4	.....	bf
5723.986	4.107	....	0	0	dr
4.224				0	
5727.242	.271	Ti-V	2N	2	
5729.122	.096	Y	00d?	0	
5730.114	.116	....	0000	0	
5731.399	.437	V	00	1	w
5731.845	.984	Fe	4	0	dr
2.146				0	
5732.941	.948	....	000	0	
5737.300	.288	V	0	0	
5740.182	.195	Ti	0	0	
5748.018	.176	Fe	2	0	dr
.374				0	
5750.757	.723	....	000	0	w
5753.701	.860	–Cr	1N	0	dr
.997				0	
5754.750	.881	Ni	5	0	dr
5.024				0	
5756.390	.410	....	0000	0	
5758.738	.....	....	....	0	
5758.967	.978	....	000	0	
5760.908	1.052	Ni	2	0	dr
1.194				0	
5761.678	.800	....	0	0	dr
.906				0	
5762.474	.479	Ti	000Nd?	3	
5763.084	.218	Fe	6	0	dr
.359				1	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5766.547	.550	Ti	0	2	
5769.094	.120	Ce	000N	1	
5769.285	.295	La	000	2	w
5770.741	.714	Ce	000Nd?	1	w
5772.628	.630	V	000	0	
5774.243	.250	Ti	0	2	
5775.160	.304	Fe	4	0	dr
.422				0	
5775.970	.969	....	0000	0	w
5780.922	1.024	Fe	0	0	dr
1.202	.130	Cr, Ti	00	0	
5782.198	.313	....	3	0	dr
.507	.390	Cu?	3	0	
5784.760	.879	Fe	1	0	dr
.992				0	
5785.372	.498	Fe	3	0	dr
.625				1	
5786.209	.193	Ti, Cr	0N	3	
5786.416	.373	....	000	1	
5788.	.141	Cr	4	.....	bf
5788.572	.504	....	000	0	w
	.611	Cr	00		
5789.551	.565	....	0000	0	
5791.064	.174	Cr	4	0	dr
.366	.243	Fe	3	1	
5793.127	.292	....	3	0	dr
.421				0	
5794.020	.137	Fe	2	0	dr
.243				1	
5797.816	.815	Ti, La	000	2	
5798.	.077	....	3	.....	bf
5804.473	.479	Ti	0	2	
5804.990	.996	....	0000	1	w
5805.992	.986	La	0	0	
5809.	.439	Fe	4	.....	bf
5811.825	.823	Nd	000Nd?	1	w
5812.	.139	Fe	0	.....	bf
5815.	.441	Fe	0	.....	bf
5817.159	.299	V	0	0	dr
.456				0	
5817.726	.708	....	000	0	
5827.968	8.097	....	0	0	dr
8.253				0	
5830.891	.895	V	000	0	
5835.482	.475	....	000	0	
5842.619	.600	Nd	000	1	
5845.346	.509	....	0	0	dr
.612				0	
5846.494	.487	V	00	1	
5853.796	.902	Ba	5	1	dr
4.012				1	
5855.	.300	Fe	1	.....	bf

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
5857.518	.674	Ca	8	0	dr
.820				0	
5862.	.582	Fe	6	.....	bf
5863.906	.933	La	0000	1	
5866.548	.675	Ti	3	1	dr
.800				0	
5867.	.785	Ca	2	.....	bf
5875.838	......	He	....	50	
5876.174	......	He	....	5	
5879.514	.506	....	0000	0	
5884.	.028	Fe	4	.....	bf
5889.979	0.186	Na	30	3	dr
90.376				3	
5895.984	6.155	Na	20	3	dr
6.347				3	
5905.725	.895	Fe	4	0	dr
6.073				0	
5916.340	.475	Fe	3	1	dr
.623				0	
5930.	.406	Fe	6	.....	bf
5937.828	8.035	Ti	000	0	dr
8.222				0	
5949.	.566	Fe	1	.....	bf
5952.	.943	Fe	4	.....	bf
5956.770	.923	Fe	4	0	dr
7.084				0	
5965.894	6.055	Ti	2	0	dr
6.231				1	
5967.684	.720	....	0000	1	w
5978.696	.768	Ti	1	0	dr
.858				0	
5983.760	.908	Fe	5	0	dr
4.040				0	
5985.	.040	Fe	6	.....	bf
5987.140	.290	Fe	5	0	dr
.451				0	
5991.605	.600	....	2	3	
6003.079	.239	Fe	6	0	dr
.416				0	
6006.587	.605	....	00	0	
6008.632	.785	Fe	6	0	dr
.941				0	
6013.556	.715	Mn	6	1	dr
.878				1	
6016.700	.861	Mn	6	1	dr
7.015				1	
6018.009	......	....	....	0	
6021.853	2.016	Mn	6	1	dr
2.171				1	
6024.	.281	Fe	7	.....	bf
6027.133	.274	Fe	4	1	dr
.421				0	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
6034.416	.440	Nd	0000	0	
6042.155, .447	.315	Fe	3	0, 0	dr E
6043.580	......	Ce	....	1	
6049.327	.337	Co	000N	1	w
6056.178, .364	.227	Fe	5	0, 0	dr
6060.860	.853	....	0000	0	
6065.557, .852	.709	Fe	7	1, 1	dr
6078.420	.410	....	0000N	0	
6081.655	.665	V	0	0	
6082.628	.640	Co	000Nd?	0	
6082.	.930	Fe	1	.....	bf
6084.320	.325	....	0	2	
6085.	.470	Ti, Fe	2	.....	bf
6086.874	.885	Co	0000N	1	w
6090.406	.429	Ti, V	2	0	
6091.231, .577	.395	Ti	0	0, 0	dr
6092.114	.133	....	1	0	
6098.864	.870	....	00	1	
6102.780, 3.105	.937	Ca	9	1, 1	dr
6103.	.400	Fe	4	.....	bf
	.514	Fe	1	.....	bf E
6108.164, .500	.334	Ni	6	1, 0	dr
6111.	.290	Ni	2	.....	bf
6111.864	.872	V	0d?	1	
6113.551	.538	....	0	1	
6119.736	.740	V	1	0	
6119.956	.970	Ni	0	1	E
6122.	.434	Ca	10	.....	bf
6125.054, .403	.236	Ni	1	0, 0	dr E
6135.562	.580	V	00N	1	
6136.665, .982	.829	Fe	8	1, 1	dr
6137.	.915	Fe	7	.....	bf
6141.816, 2.065	.938	Fe, Ba	7	2, 2	dr
6146.422	.445	Ti	000	0	
6147.932	.950	Fe	2	2	E
6149.457	.458	Fe, Nd	2	2	w E
6150.338	.360	V	0Nd?	0	
6151.037	.052	Y	0000	1	
6151.	.834	Fe	4	.....	bf
6154.315, .540	.438	Na	2	0, 0	dr
6157.	.945	Fe	5	.....	bf
6160.	.956	Na	3	.....	bf
6162.	.390	Ca	15	.....	bf
6165.	.577	Fe	3	.....	bf
6166.521, .790	.651	Ca	5	0, 0	dr
6169.	.249	Ca	6	.....	bf
6169.	.778	Ca	7	.....	bf
6173.426, .687	.553	Fe	5	0, 0	dr
6180.	.420	Fe	5	.....	bf
6188.080, .331	.210	Fe	4	0, 1	dr
6191.	.393	Ni	6	.....	bf
6191.612, .930	.779	Fe	9	0, 0	dr
6199.392	.398	V	0	1	
6200.370, .680	.527	Fe	6	1, 1	dr
6204.	.825	Ni	1	.....	bf
6210.869	.895	Sc	00N	0	
6213.497, .811	.644	Fe	6	1, 1	dr
6215.241, .489	.360	Fe	5	0, 0	dr
6219.378, .660	.494	Fe	6	1, 1	dr
6229.340, .539	.437	Fe	1	0, 0	dr
6230.	.943	V-Fe	8	.....	bf
6232.639, 3.040	.856	Fe	3	1, 1	dr
6237.	.534	....	3	.....	bf
6238.592	.598	Fe	2	3	E
6239.611	.585	Sc	00	0	
6240.737, .988	.863	Fe	3	1, 1	dr
6243.300	.320	....	1	0	
6245.802	.832	Sc–	1	0	
6246.398, .666	.535	Fe	8	1, 1	dr
6247.777	.774	Fe	2	2	E
6252.658, .901	.773	Fe	7	1, 0	dr
6256.	.572	Ni-Fe	6	.....	bf
6265.198, .494	.348	Fe	5	0, 0	dr
6270.259, .608	.442	Fe	3	0, 0	dr
6272.239	......	Ce	....	1	
6274.049	......	....	....	0	
6280.679, .977	.833	Fe	3d	0, 1	dr
6287.023	.009	V	0000N	0	

TABLE I—*Continued*

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
6291.022	.184	Fe	4	0	dr
.319				0	
6298.	.007	Fe	5	......	bf
6301.560	.718	Fe	7	0	dr
.871				0	
6302.560	.709	Fe	5	0	dr
.861				0	
6305.873	.878	Sc	0000	1	w
6311.610	.722	Fe	1	0	dr
.834				0	
6314.	.876	Ni	4	......	bf
6315.805	6.028	Fe	1	0	dr
6.241				0	
6318.	.239	Fe	6	......	bf
6322.713	.907	Fe	4	0	dr
3.091				0	
6324.759	......	......	......	0	
6327.615	.820	Ni	2	0	dr
8.034				0	
6330.126	.316	Cr	1	0	dr
.489				0	
6331.	.067	Fe	2	......	bf
6335.409	.554	Fe	6	0	dr
.689				0	
6336.842	7.048	Fe	7	0	dr
7.341				1	
6347.335	.310	......	2N	2	
6355.045	.246	Fe	4	0	dr
.488				0	
6358.722	.898	Fe	6	0	dr
9.045				0	
6362.579	.560	Zn	1	0	
6362.930	3.090	Cr, Fe	2	0	dr
3.264				0	
6364.455	.575	Fe	1	0	dr
.712				0	
6369.663	.683	Fe	0	4	
6371.592	.573	Fe	1Nd?	2	
6378.	.468	Ni	2	......	bf
6380.762	.958	Fe	4	0	dr
1.140				0	
6381.836	.844	......	0000	0	
6383.916	.932	Fe	0N	1	w E
6390.706	.715	La	000	1	
6393.	.820	Fe	7	......	bf
6395.390	.378	Co	00Nd?	0	
6408.606	.587	Co	0000	0	
6411.637	.865	Fe	7	0	dr
2.070				0	

Observed λ	Rowland λ	Rowland Element	Rowland Intensity	Chr. Int.	Remarks
6417.120	.133	Fe?	1	3	E
6420.	.169	Fe	4	......	bf
6421.402	.570	Fe	7	0	dr
.753				0	
6430.870	1.066	Fe	5	0	dr
1.251				0	
6432.870	.895	Fe?	1	6	
6439.113	.293	Ca	8	1	dr
.481				1	
6449.844	0.033	Ca	6	0	dr
50.253				0	
6455.218	.230	Co	0N	1	
6455.602	.820	Ca	2	0	dr
6.043				0	
6456.597	.603	Fe	3	5	E
6462.	.784	Ca	5	......	bf
6469.	.408	......	2	......	bf
6471.677	.885	Ca	5	1	dr
2.109				1	
6475.	.846	......	2	......	bf?
6491.810	.800	Ti	1	0	E
6493.805	4.004	Ca	6	0	dr
4.232				0	
6496.978	7.128	Fe	4	2	dr
7.291				2	
6498.995	9.168	Fe	1	0	dr
9.371				0	
6499.676	.880	Ca	4	0	dr
6500.096				0	
6516.310	.311	Fe	2	7	E
6527.198	.444	......	1	1	dr
.656				0	
6546.311	.479	Ti-Fe	6	0	dr
.675				0	
6554.322	.470	Ti	0	1	dr
.625				0	
6555.087	.080	......	0000N	0	
6555.718	.700	......	1N	0	
6559.659	.815	......	0	0	dr
.949				0	
6562.299				20	dr
3.618	.045	H	40	10	
.902				10	
6569.	.460	Fe	5	......	bf
6586.547	.550	Ni	1	0	
6599.320	.353	Ti	∞	0	

sun's visible edge, it seems certain that the results of these observations relate to a very low level in the reversing layer. We are, therefore, quite unable to agree with Mitchell in his conclusion that the spectra taken without an eclipse are at a higher level than the eclipse photographs. In fact the arguments which he adduces, namely, the absence from the Mount Wilson negatives of some strong Fraunhofer lines, which are prominent as bright lines on the eclipse negatives, and, similarly, the strength as bright lines of certain faint Fraunhofer lines point to precisely the opposite conclusion and can be explained only on the basis of a lower level for the photographs taken without an eclipse.

COMPARISON WITH ECLIPSE RESULTS

In the course of the discussion of his admirable eclipse results Mitchell institutes a comparison with the values published by Hale and Adams in their preliminary account of the Mount Wilson observations. From this comparison Mitchell concludes:

1. The eclipse spectrum negatives show twice as many lines as the 60-foot tower telescope photographs.

2. The eclipse spectrum wave-lengths are quite as accurate as those obtained from the tower telescope photographs.

It is difficult to understand the basis for the first of these conclusions unless Mitchell has employed for comparison purposes the violet part of the spectrum in which the visual objective of the tower telescope performs to poor advantage. Certainly in the visual region no such conclusion is tenable on the evidence either of the short region between λ 5111 and λ 5198 previously published, or of the present more complete results. A comparison for the entire region between λ 4800 and λ 5880 shows the following number of bright lines, the double reversals being counted as single lines:

	Mitchell Eclipse	Mount Wilson
Bright lines (measured)	901	894
Dark lines with bright fringes (not measured)	....	133
Total	901	1027

The effect of the difference of level in the reversing layer for the two sets of photographs is seen clearly in these results. Nearly all of the lines with bright fringes on the Mount Wilson photographs appear on Mitchell's negatives as strong bright lines, and the same is true of a large proportion of the Mount Wilson double reversals. A considerable number of strong lines on the eclipse plates do not appear at all as bright lines on the tower telescope plates. This is due evidently to the low level at which the latter were taken. On the other hand, the tower telescope photographs show between one and two hundred lines not seen on the eclipse photographs, essentially all of which are very faint Fraunhofer lines and belong to a low level in the reversing layer. The two series of photographs, accordingly, may be said to represent the spectrum of two sections of the reversing layer at different elevations, to the higher of which the eclipse results belong.

The statement by Mitchell that the degree of accuracy attained for the eclipse and the tower telescope results is about the same is by no means borne out by a detailed comparison. For this purpose we have selected only the single lines common to both sets of measures, omitting all blends and double reversals. A comparison of all of the lines of this character between λ 4800 and λ 5300 gives for the average deviation from Rowland's wave-lengths the following values:

Eclipse Results	Mount Wilson Results
0.029 A	0.011 A

For the entire region between λ 4800 and λ 5880 the results are

Eclipse Results	Mount Wilson Results
0.030 A	0.012 A

It appears, therefore, that the average deviation from Rowland's wave-lengths of the eclipse spectrum lines is about two and one-half times as great as that of the lines from the tower telescope photographs. The well-known very high degree of precision in the relative wave-lengths of Rowland's table necessitates ascribing essentially all of these differences to errors in the determination of the bright-line wave-lengths.

DISCUSSION OF THE RESULTS

In general the results obtained for the chromospheric spectrum agree with eclipse results as regards the elements represented by the largest proportion of bright lines. They differ widely, however, in the matter of the relative intensity of the bright lines as compared with the dark lines of the solar spectrum. With the exception of the hydrogen, magnesium, and sodium lines, and enhanced lines in general, only very few strong dark lines of the solar spectrum are represented by strong bright lines in the chromospheric spectrum taken without an eclipse. Such lines usually remain dark with a faint bright fringe on either edge. As already stated, this is almost certainly due to the low level of the point under observation. The stronger lines of the solar spectrum are accompanied by wings, similar in character to those of the H and K lines of calcium, though very much less in extent and intensity, which are due to the dense vapor at the base of the sun's reversing layer. In observations at the sun's edge these wings appear as faint emission lines, while the central portion of the line, due mainly to gas at a higher level, still remains dark. The phenomenon is in fact just the same as in the case of the well-known double reversals of the calcium and hydrogen lines at the sun's limb.

It seems probable that double reversal is a universal characteristic of all lines in the chromospheric spectrum at a low level, and that failure to observe it in any particular case is due to the faintness of the lines or insufficient resolving power of the spectroscope. Mitchell observed the effect for a few of the stronger lines, even at the level of his eclipse spectra, and several hundred examples are shown in these tables. In most cases the intensities of the two bright components are equal, and when unequal there seems to be no especial preponderance either of the violet or the red component.

The great number of very faint dark lines of the solar spectrum, which are represented by bright lines in the chromosphere, is in excellent accord with St. John's conclusions that such lines are produced at a low level in the solar atmosphere. A large number of these lines in the region λ 5050–λ 5165 may be ascribed to the green carbon fluting. Many others have been identified with

reasonable certainty with lines of cobalt, scandium, titanium, vanadium, and the heavy elements, all of which are very strongly represented in the chromospheric spectrum. It seems probable that a portion of the unidentified lines may be due to the fainter enhanced lines of elements which have as yet been but very imperfectly investigated in this portion of the spectrum.

Some special lines.—The two hydrogen lines which appear in this region are H_α and H_β. Both are strong double reversals in the chromosphere with the components of nearly equal intensity. A peculiar feature is the apparent doubling of the red component of H_α. This is without doubt due to the presence of the strong atmospheric line at λ 6563.763 (the photographs were taken at low sun) which falls upon the center of the bright component and so gives the appearance of a double line.

Of the three helium lines, those at λ 4922 and λ 5048 probably are present, but the first so nearly coincides with a strong La line that it cannot be distinguished with certainty. The D_3 line is the strongest bright line on our photographs, and the scale of the plates is sufficient to make the measurement of its two components possible. The separation found, 0.336 A, agrees closely with the laboratory results.

The D lines of sodium and the b lines of magnesium are very similar in their behavior, being broad double reversals with components of moderate intensity.

A peculiar feature of the results is the remarkable number of faint cobalt lines represented in the chromosphere. In this respect cobalt is to be classed rather with titanium and vanadium than with nickel, iron, and manganese.

The enhanced lines.—It appears from these results that the enhanced lines are of an exceptionally great intensity at a moderate level in the solar atmosphere, just as eclipse observations have shown them to be at a higher level. Upon our photographs they nearly always appear as double reversals, but the separation of the components is considerably less than in the case of arc lines which are doubly reversed. In discussing possible explanations of the prominence of enhanced lines in the flash spectrum Mitchell has referred to the suggestion made by Gale and Adams that it

may be due to the reduction of pressure in the upper portions of the solar atmosphere, laboratory observations having shown that in the case of several elements reduced pressure brings out the enhanced lines more strongly. A second suggestion made by the same writers may also be considered in this connection. It was found that in the spectrum of a spark under moderate pressures comparable with those at the base of the reversing layer the enhanced lines remained bright when the other lines became dark. It would appear probable, therefore, that in the solar spectrum the enhanced lines would be represented by dark lines relatively less intense than would the arc lines. The relative gain in intensity of the enhanced lines when appearing as bright lines in the chromosphere would, accordingly, be due to two causes: first, the actual increase in relative intensity of the enhanced lines due to reduction of pressure; second, the relative weakness of the dark lines in the solar spectrum with which the comparison is made.

Elements of high atomic weight.—The extraordinary prominence of the lines of certain elements of comparatively high atomic weight in the flash spectrum is a well-known feature of eclipse results. Without following Mitchell in his identification of a larger number of lines with those due to praesodymium, samarium, and erbium, we are certainly justified in concluding this behavior in the chromosphere on the part of yttrium, lanthanum, cerium, and probably neodymium.

According to the conclusions of St. John and others, elements of high atomic weight lie at low level in the solar atmosphere. Mitchell concludes from his measurement of the lengths of the arcs of the flash spectrum lines of the rare earths that these do not occur in shallow layers, but rather the reverse. It is, of course, evident that the two sets of results cannot be compared directly if Mitchell is to include among his rare earths scandium, with an atomic weight of 44, and omit barium with an atomic weight of 137. The evidence afforded by the results given here appears to be distinctly in favor of St. John's conclusions. The relative intensities of the bright lines of the heavy elements become greater as we pass from eclipse spectra to the lower level of the observations without an eclipse. Thus if we compare a lanthanum line of solar intensity 1

with an iron line of intensity 1, we find a certain ratio of intensity for the two bright lines in eclipse spectra. In the spectra taken without an eclipse the lanthanum bright line is relatively stronger than in the eclipse spectra. This can hardly be interpreted in any other way than that the radiation of the heavy elements becomes relatively stronger at low levels. The case appears to us analogous to that of the carbon fluting, the individual bright lines of which show the more strongly the nearer the observations are made to the sun's visible edge.

It seems very probable that, as St. John has stated in his discussion of Mitchell's eclipse results, the explanation of the longer arcs found by Mitchell for the rare earths is to be found in the greater intensities of these lines. The average intensity given by Mitchell for the bright lines of the Fe group is 1.07; for those of the rare earths 3.10. There can be little doubt that a bright arc three times as strong as another would on the photographic plate have a considerably greater length. The case is entirely similar to that seen in the laboratory when a photograph is taken of the spectrum of a metallic arc. The strongest lines are the longest even when the lines compared are produced in just the same part of the arc.

Chromospheric wave-lengths and anomalous refraction.—In our determinations of the wave-lengths of the bright lines in the chromosphere we have used as standards of reduction the dark lines of the limb spectrum which appear upon the same photographs. Any differences of wave-length, therefore, are with reference to the lines at the sun's limb, and these, as is well known, are displaced slightly to the red when compared with the center of the sun. In the region covered by the observations this displacement amounts on the average to +0.008 A. Our chromospheric measures give for the average difference in wave-length between 512 identified bright lines and the corresponding dark lines at the limb −0.002 A. If we assume this small difference to be real, the bright lines in the chromosphere, therefore, will be displaced +0.006 A relative to the dark lines at the center of the sun.[1]

[1] In the results given by Hale and Adams the same method was used, and the wave-lengths given were referred to the lines at the sun's limb. Apparently some

The ordinary absorption and emission theory of the origin of the solar lines would explain this result in a very simple way. The chromospheric bright lines are produced at nearly the same level and under nearly the same physical conditions as the dark lines at the sun's limb; hence their wave-lengths should be closely the same. On the whole we should perhaps expect the level of the chromospheric observations to be slightly above that of observations at the sun's limb. If such is the case the cause which produces the displacements of the lines at the limb relative to the center of the sun (which we are still inclined to consider in large part as pressure, in spite of Evershed's recent work on the subject) would operate to a less extent on the bright lines; and we might expect some such small negative difference as is found between their wave-lengths and those of the dark lines at the limb.

In the course of an extensive series of articles Julius has endeavored among other solar phenomena to account for the wave-lengths of the chromospheric lines and for the displacements of the dark lines at the sun's limb on the basis of anomalous refraction and dispersion in the solar atmosphere.[1] The principal feature of the explanation which he adopts is the assumption that the solar atmosphere is honeycombed with irregular density gradients, of which a sufficient number show increasing density outward to overcome wholly or mainly the effect of the well-known regular radial gradient. Most solar observers would desire some evidence tending to indicate the existence of such gradients apart from the necessity of postulating them in order to support the anomalous refraction hypothesis, more especially as they must be essentially permanent in character. If they fluctuated to any considerable

misapprehension has arisen in regard to this matter, as both Julius and Brunt (*Monthly Notices*, **73**, June 1913) appear to consider the wave-lengths as referred to the center of the sun. No explicit statement was made because at the date the results were published the amount of the hypothetical anomalous dispersion effect, due to the regular density gradient, was supposed to be very large, amounting to one-half the width of the lines. The value given by Hale and Adams for chromosphere-limb wave-lengths was +0.002 A; the result found here is −0.002 A. We consider this agreement as quite satisfactory in view of the difficulty of the measurements.

[1] "On the Origin of the Chromospheric Light," *Proceedings Amsterdam Academy*, December 23, 1909; "Regular Consequences of Irregular Refraction in the Sun," *Proceedings Amsterdam Academy*, October 28, 1909.

extent, both the displacements at the sun's limb and the wave-lengths of the chromospheric bright lines should show marked systematic variations, and such has not been found to be the case. Assuming the existence of such irregular gradients, however, Julius accounts for the displacements of the dark lines at the limb as follows:

> Indeed rays coming from the limb have, as a rule, accomplished a longer distance through the solar gases than rays coming from the center, and, therefore, were more subject to loss of intensity by the process of incurvation towards the photosphere. The amount of the irregular ray-curving depends on the absolute magnitude of Rm Δm (the refracting power of the mixture of gases), which near the weaker lines of the solar spectrum is sensibly greater with red than with violet light. So the lines must chiefly widen at their red-facing side, in proportion as the opportunity for losing light increases.

That is, the displacements are due to the widening of the lines toward the red owing to the relatively greater loss of red light by anomalous refraction. In this explanation the effect of the regular radial gradient is neglected completely, and in fact in another place[1] Julius states expressly that it would produce displacements toward the violet. Accordingly he is obliged tacitly to assume that the irregular gradients are sufficient to counteract this effect and to give in addition the observed displacements toward the red.

When he passes to the discussion of the chromospheric spectrum Julius again makes use of the irregular density gradients, but in this case he considers they will produce essentially symmetrical bright lines, violet and red light being refracted in nearly equal proportions. As already stated, Julius has not understood the fact that the chromospheric lines are displaced to the red relative to those at the center of the sun by about 0.006 A, since his explanation is intended to account for the absence of any displacement. The photospheric light which is refracted to form the chromospheric lines is supposed to come from near and just beyond the sun's visible edge.

It seems to us very doubtful whether the results found on our photographs can be accounted for by this hypothesis. Bright and

[1] *Astrophysical Journal*, 31, 427, 1910.

dark lines appear on the same negatives and the character of the path through the irregular density gradients must be nearly the same in the two cases. If the displacements of the dark lines at the sun's limb are due to irregular density gradients which tend to produce a loss of light on the red side of the absorption lines and thus widen them toward the red, we must conclude that these gradients would have a marked effect upon the light which forms the chromospheric lines. Accordingly if the photospheric light which is refracted comes from beyond the sun's limb, we should expect a relative loss either of red or of violet light. If the former the chromospheric lines should be displaced to the violet with regard to the dark line at the limb; if the latter it should be displaced to the red. Neither is the case to any marked degree. Apparently the lack of symmetry in refraction which is introduced by Julius to account for the dark line displacements is directly opposed to the chromospheric results. A resort to the regular radial gradient to explain the displacements of the chromospheric lines with reference to the lines at the center of the sun could not be made unless the explanation of the limb displacements were abandoned, since this would require displacements to the violet.

The results of a comparison of the wave-lengths of the chromospheric lines with the corresponding dark lines at the sun's limb are given in Table II. Only such lines have been included as can be identified with certainty, and whose wave-lengths have been measured directly.

TABLE II

Element	No. Lines	Chromosphere—Limb
Fe	157	−0.001 A
C	90	−0.002
Ti	87	−0.004
Co	42	−0.008
Cr	35	+0.002
Ni	32	−0.001
V	27	−0.003
Ca	16	0.000
Sc	13	−0.001
Y	8	−0.004
La	5	+0.006
Mean	512	−0.002

The preponderance of the negative sign in these residuals is rather striking, the only important exception being chromium. Since the average deviation for all of the lines measured amounts to 0.012 A, however, we do not feel justified in considering the slight mean residual of −0.002 A as certainly real.

One other characteristic of the chromospheric lines should be considered in connection with the anomalous dispersion theory. This is the phenomenon of double reversal. Although Julius admits that a portion of this effect may be due to common reversal by absorption, he introduces anomalous refraction and scattering of the light very close to the absorption lines to increase its amount. Two comments may be made in this connection. First, it would seem hardly necessary to bring anomalous refraction into question if the existence of absorption has to be assumed, since laboratory results have shown that it is easy to produce in the spectra of luminous gases just such reversals as are found in the chromospheric spectrum under conditions where only emission and absorption are involved. Second, it is difficult to understand why the double reversals should nearly always be symmetrical, although the refracting power of the solar atmosphere is greater on the red side of an absorption line.

It is a peculiar fact that the advocates of the anomalous dispersion hypothesis admit the existence of essentially all of the phenomena in the sun which are required by those who use the more usual explanation. Thus Julius is willing to admit the presence of ordinary selective absorption and emission to form the central portions of the Fraunhofer lines; double reversal may help to form the double lines in the chromosphere; the Doppler effect is essential in the convection currents required to produce his hypothetical irregular gradients; the existence of pressure can hardly be denied in any gaseous atmosphere; and variations in density are the fundamental basis of anomalous refraction theory. Apparently variations in temperature have not as yet been admitted by Julius, but it is certainly impossible to explain on the anomalous refraction theory the presence in sun-spots of a band spectrum not found at all in the solar spectrum. If the reduction in temperature is once admitted, the spectral characteristics of sun-spots

find not only a ready but a necessary explanation in this fact, as laboratory investigations have shown. Many of the solar applications of anomalous dispersion share this characteristic of being quite superfluous.

Some features of the absorption spectrum on the chromosphere photographs.—The dark lines which appear upon our chromospheric photographs are due to the light from just within the sun's limb and represent the limb spectrum in its most extreme form. In general the changes in the character and intensity of the lines as compared with the center of the sun are those described by Hale and Adams in their publication on the subject[1] some years ago. They are, however, somewhat more pronounced, a result to be expected because of the closer proximity of the point under observation to the sun's limb. In one region of the spectrum, at least, its characteristics deserve a few words of comment.

Between the limits λ 5025 and λ 5150 there are some especially remarkable changes in the spectrum, consisting in the great intensification of certain very faint solar lines, the great weakening of some strong solar lines, and the appearance of several fairly strong lines which apparently are not present in the solar spectrum at all. The changes are such as to modify the spectrum completely and to render its comparison with the usual solar spectrum difficult.

The results of some measurements in this region are given in Table III.

There are some indications of the presence of a banded spectrum in certain portions of this region, especially near λ 5065, λ 5080, and λ 5100. It is possible that this is a trace of the band spectrum of magnesium hydride found by Fowler to be so prominent in the spectrum of sun-spots.

SUMMARY

1. Photographs of the flash spectrum taken with the 60-foot tower telescope show a slightly greater number of bright lines than the eclipse photographs of Mitchell in the same region.

[1] *Mt. Wilson Contr.*, No. 17; *Astrophysical Journal*, **25**, 300, 1907.

2. The degree of accuracy in the determination of wave-lengths is between two and three times as high for the photographs taken without an eclipse.

3. The level of the observations is decidedly lower in the case of the tower telescope results.

4. Double reversal is probably a universal characteristic of the bright lines.

TABLE III

Wave-Lengths		Intensity		Character at Limb
Limb	Sun	Limb	Sun	
5034.259	....	1	....	
5034.737	....	2	....	Double
5035.506	.542	3	5	Double
5036.105	.115	2	5	Blend in sun
5037.458	.436	2	000	Blend in sun
5037.869	.885	2	000	
5040.429	.422	1	000	
5043.055	....	1	....	Narrow
5043.218	....	2	....	Narrow
5043.758	.761	1	00	
5044.107	....	1	....	
5056.608	.617	1	000	Narrow
5057.745	{.665 / ....}	2	{0 / ...}	Broad
5061.287	....	1	....	
5076.432	.450	1	3	
5076.595	{.504 / .666}	2	{000 / 0000}	
5086.791	.794	1	0000	
5094.584	.594	1	0	Broad
5097.669	.668	1	0	
5103.148	.142	2	1	
5149.037	.013	2	000	

5. The lines of the elements of high atomic weight are relatively stronger on the photographs taken without an eclipse. This indicates a low level for these elements in the solar atmosphere.

6. The average difference in wave-length between the bright lines of the chromospheric spectrum and the dark lines at the sun's limb is -0.002 A.

7. This close agreement in wave-length does not appear to be in accordance with the anomalous refraction theory of the chromosphere as developed by Julius.

8. Some remarkable differences have been found in the dark line spectrum at the sun's limb as compared with the ordinary solar spectrum. Several new lines appear in addition to great changes in intensity of certain solar lines. There is considerable evidence of the presence of a band spectrum in a portion of the green region of the spectrum.

Mount Wilson Solar Observatory
November 1914

ON THE SIMPLEST FORM OF THE STELLAR INTERFEROMETER FOR DETERMINING THE ANGULAR DIAMETERS OF STARS BY MEANS OF ELLIPTICALLY POLARIZED LIGHT

By S. POKROWSKY

Two pencils of parallel rays, 1, 2, proceeding from any star fall at the angle of complete polarization upon transparent plane-parallel glass plates, I and II. The pencil reflected by the plate I will be completely polarized in the plane of incidence; it will pass through the plane-parallel $\frac{\lambda}{2}$ plate of quartz, the principal section of which is at 45° with the plane of incidence; therefore the plane of its polarization will be rotated through 90° and it will be totally refracted through the plate II and superposed on the pencil 2 reflected by the latter. Since the vibrations in the rays 1 and 2 are coherent, at the instant when they reach the parallel plates as natural light they will give, after coincidence, rays elliptically polarized. On carefully adjusting the interferometer, the field of view will be homogeneous (*teinte plate*) when examined through a nicol. In consequence of the great angles of incidence of the rays 1 and 2 upon the plates I, II, there will be a very great difference of path between them. Consequently the pencil 2 must be previously reflected by the mirrors R and R_1 in such a manner that the path $R\,R_1\,O_1$ will be equal to the path $O\,O_1$. After coincidence the rays follow the ordinary route[1] through the objective, the Wollaston double-image prism W, the astrophotometer p, and finally the ocular O. V, V_1 are two plane-parallel plates of glass to compensate for the difference in path of the rays 1 and 2.

Passing to the evaluation of the optical sensitiveness of the above-described interferometer we can neglect the interference of light in each of the plane-parallel plates I and II; for we suppose that they are sufficiently thick.

[1] S. Pokrowsky, *Astrophysical Journal*, **36**, 156, 1912.

Let us estimate the intensity of the beam transmitted by the interferometer to the eye, when natural light of unit intensity is incident upon the plate V; through it will pass

$$\frac{1-\rho}{1+\rho},$$

where

ρ is the coefficient of reflection $=\left(\frac{\mu-1}{\mu+1}\right)^2$

μ is the refractive index for the glass plate V.

The plate I will reflect at the angle of complete polarization

$$\frac{1-\rho}{1+\rho}\times\frac{2r}{1+r}$$

where

$$r=\frac{1}{2}\left(\frac{n^2-1}{n^2+1}\right)^2$$

and n is the refractive index of the glass plate I. Through the plate marked $\frac{\lambda}{2}$ will pass approximately

$$\frac{1-\rho}{1+\rho}\times\frac{2r}{1+r}\left[1-\left(\frac{\mu'-1}{\mu'+1}\right)^2\right]^2=\frac{1-\rho}{1+\rho}\times\frac{2r}{1+r}\times 0.95^2\,;$$

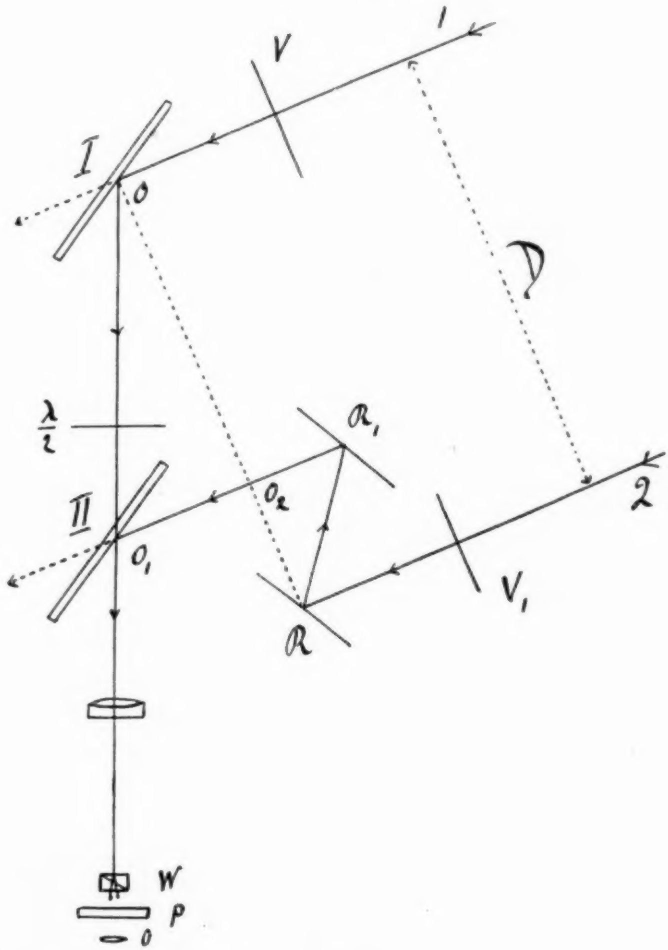
$\mu' \doteq 1.5$ is the average refractive index for quartz. This quantity of rays polarized perpendicularly to the plane of incidence will be totally refracted through the second plate II.

In order to simplify the calculations, we assume that through each of the following eleven surfaces, namely, the three surfaces of the objective; the three surfaces of the double refracting prism; the three surfaces of the astrophotometer, and finally the two surfaces of the eyepiece, passes 95 per cent of the light falling on it, and that moreover about 5 per cent of the light will be absorbed in this apparatus; then the energy that reaches the eye will be

$$\frac{1-\rho}{1+\rho}\times\frac{2r}{1+r}\,0.95^{14}\,.$$

This value must be doubled because the plate II also gets the same quantity of luminous energy. Consequently we shall have

$$\gamma = 2 \times 0.95^{14} \frac{1-\rho}{1+\rho} \frac{2r}{1+r}.$$



For the approximate calculation we will take

$$\mu = 1.5; \; n = 1.487.$$

Then

$$\log \gamma = 9.07608.$$

The minimum value of the angular diameter ω to be discovered by the proposed interferometer will be determined by the expression[1]

$$\omega = \frac{4}{\pi} \frac{\lambda}{D} 2.5^{-\left[\frac{K-p}{2} + 1.25 \log \frac{S}{\sigma} \gamma\right]}$$

where

D is the distance between the pencils 1 and 2;

K is the magnitude of a star of the minimum intensity perceptible to the eye;

p is the magnitude of the observed star;

S is the effective area of the objective, determined by the dimensions of the quartz plate;

σ is the area of the pupil of a normal eye; and

γ is the coefficient indicating what fraction of the luminous energy falling on the interferometer reaches the eye.

Assuming

$$\lambda = 5.6 \times 10^{-5} \text{ cm}$$
$$D = 100 \text{ cm}$$
$$k = 6$$
$$S = 10 \times 10 \text{ cm}^2 = 10^4 \text{ mm}^2$$
$$= 4\pi \text{ mm}^2$$
$$\log \gamma = 9.07608$$
$$1'' = 4.84 \times 10^{-6} \text{ in angular measure,}$$

we shall find

for stars of the first magnitude ($p = 1.0$)

$$\omega_1 = 0''.0016$$

for stars of 0.0 magnitude ($p = 0.0$)

$$\omega_0 = 0''.0009;$$

for Sirius ($p = -1.7$)

$$\omega_S = 0''.0006.$$

The above-mentioned values of ω, which can be discovered by means of the described interferometer, were obtained on the assumption that the laws of reflection and refraction of polarized light are expressed very approximately by Fresnel's formulae. As may be seen from the few results which we have at present,

[1] S. Pokrowsky, *op. cit.*, p. 163.

these formulas are confirmed with a precision of 1 to 2 per cent. The condition of the surface-layer of glass and the kind of polish exert a very considerable influence. Lord Rayleigh has shown that only freshly polished glass surfaces give the results in accordance with those of Fresnel; some months later the divergence between theory and practice may amount to as much as 10 to 30 per cent.

Immediate observation shows that rays reflected at the angle of complete polarization will not be entirely polarized in the plane of incidence; but there will be added a small quantity of rays polarized perpendicularly to the plane of incidence; for abbreviation let us name them "residual" rays. The ratio of the amplitudes of the luminous vibrations in these rays to the amplitudes of the luminous vibrations in the rays polarized in the plan of incidence (that is to say, of the principal rays), proportional to the coefficient of ellipticity, was determined by Jamin for a great number of solid and liquid substances; for different kinds of glass this coefficient varies from 0.03 to 0.007.[1] Knowing this coefficient we can easily determine the ratio of the intensities of the two rays which will be exceedingly small since it is proportional to the square of this coefficient.

The residual rays, polarized perpendicularly to the plane of incidence, after traversing the $\frac{\lambda}{2}$ plate will be polarized in this plane; after refraction through the plate II they will be superposed on the analogous rays polarized perpendicularly to the plane of incidence and will therefore produce rays elliptically polarized. Consequently the double refracting prism W will again yield two images of the star exceedingly feeble and coinciding with the first two. The ratio of their intensities will be the inverse of that which existed for the images already examined and formed by the rays polarized in the plane of incidence (that is to say, the principal rays), because the planes of polarization of the two residual rays will be respectively perpendicular to the planes of polarization of the principal rays. In this manner the more intense image formed by the residual rays will coincide with the feebler one produced by the principal rays and will introduce some error in the ratio of the

[1] Winkelmann, *Handbuch der Physik*, **6,** "Optik," pp. 1260–1264, 1906.

intensities of the principal images. Now it is necessary to calculate approximately the intensity (in stellar magnitudes) of the more intense image of the star formed by the residual rays. It will be advisable to employ in the proposed interferometer those kinds of glass which have the smallest coefficients of ellipticity. Consequently before inserting the glass plates, I and II, in the interferometer it will be necessary to determine carefully their coefficient of ellipticity η. I will take

$$\eta = 0.0075; \quad n = 1.487.$$

If the star under observation is of a magnitude p for the naked eye, when we observe it in the interferometer telescope the more intense of its two images will appear to be a star of the magnitude $\left(p - 2.5 \log \frac{S}{\sigma}\gamma\right)$. Since the ratio of the residual amplitudes to the principal ones is equal to

$$\epsilon = \frac{\eta}{2}\sqrt{1+n^2}$$

it will be necessary to take $\gamma\epsilon^2$ instead of γ and the intensity of the more intense image of the star in the residual rays will be of magnitude $p - 2.5 \log \frac{S}{\sigma}\gamma\epsilon^2$.

Assuming

$$S = 10^4 \text{ mm}^2$$

$$\sigma = 4\pi \text{ mm}^2$$

$$\log \gamma = 9.07608,$$

we shall find

$$2.5 \log \frac{S}{\sigma}\gamma\epsilon^2 = -5.92,$$

that is to say, if the star under observation has a magnitude p for the naked eye, the more intense of its two images formed by residual rays will, when observed in the interferometer telescope, appear to be a star of magnitude

$$p + 5.92,$$

but will introduce an error into the ratio of the intensities of the principal images only in the case of Sirius and of the stars of the magnitude 0.0.

In this case, we must accordingly diminish the aperture S of the objective, which will in turn slightly diminish the optical power of the interferometer.

Physical Laboratory, Electro-technical Institute
Petrograd
September 1914

THE DIFFERENT CHARACTER OF SPECTRUM LINES BELONGING TO THE SAME SERIES

By T. ROYDS

It has been generally assumed that the spectrum lines belonging to the same series are similar in character and in behavior under varying experimental conditions. Indeed the similarity in sharpness or diffuseness, or in the direction of unsymmetrical widening, has been a valuable aid in the detection of series relationships in spectra. If, for example, the strong lines of a series were unsymmetrically widened toward the red, the continuation of the series would be looked for in lines widened in the same direction, the widening becoming greater as the higher members were reached. It is therefore of considerable importance to note that there is at least one well-authenticated series in which the character of the lines changes in the course of the series. This is the first subordinate "triplet" series of barium whose lines are given in Table I, column 4. In this series the first members (λλ 5819, 5800, 5777, 5536, 5519, 5424), consisting of a triplet and satellites, are all unsymmetrically widened toward the red; the second members (λλ 4493, 4489, 4333, 4323, 4264) and probably all succeeding are, on the contrary, unsymmetrically widened toward the violet. This is so surprising and important that it is necessary before proceeding farther to make quite sure of our facts. First, there can be little doubt that the first members do really belong to the same series as the higher members; they fit into a formula of the usual type and have the full complement of satellites analogous to the higher members and to the first subordinate series of calcium and strontium. Secondly, the character of the lines seems equally certain. Although previous investigators of the barium spectrum have not noted the character of the first members of the first subordinate series, the reversals of these lines are in my photographs very eccentrically placed on the violet side of the emission line, indicating unsymmetrical widening toward the red. The character

of the second members is obvious and is given by Kayser and Runge as unsymmetrical toward the violet.[1] There is also the evidence of the displacement at the negative pole compared with the center of the arc. I have previously shown that lines are displaced at the negative pole in the direction of their greater widening.[2] Investigating the displacement of the barium lines, I find that all the first members of the first subordinate series are displaced to the red (λ 5536.07 is interfered with by an adjacent line), and all the second members to the violet; this is complete confirmation of their opposite character.

It is interesting to examine also the analogous first subordinate series of calcium and strontium. Of the calcium series the first members are in the infra-red and their character is not known; the second members are quite symmetrical so far as can be judged from the symmetry of their reversals and from the smallness of their displacements at the negative pole of the arc,[3] but the higher members are unsymmetrical toward the violet[4] according to Kayser and Runge[5] and Eder and Valenta.[6] The calcium series is therefore not so extreme a case as that of barium but is still a noteworthy exception to the general run of series. The strontium series is, on the other hand, quite normal if we exclude the infra-red lines whose character is not known. I find that the second members have their reversals slightly eccentrically placed to the red side of their emission lines and that they are displaced to the violet at the negative pole of the arc. These facts indicate that they are unsymmetrical toward the violet and therefore uniform with the higher members whose character has already been observed.[7]

[1] Kayser, *Handbuch der Spectroscopie*, **5**.

[2] Royds, *Kodaikanal Observatory Bulletin*, No. XL.

[3] *Ibid*.

[4] Saunders (*Astrophysical Journal*, **32**, 153, 1910) gives the third members as unsymmetrical toward the *red*. This is probably a mistake. The photograph of Crew and McCauley of the arc in air (*Astrophysical Journal*, **39**, 29, 1914) shows them to be unsymmetrical toward the violet in agreement with Eder and Valenta's observation of the spark lines and mine of the arc lines.

[5] *Handbuch der Spectroscopie*, **5**.

[6] Royds, *Kodaikanal Observatory Bulletin*, No. XL.

[7] Kayser, *op. cit.*, **6**.

In brief, the higher members of the first subordinate "triplet" series of calcium, strontium, and barium are unsymmetrical toward the violet; the first members of the barium series are unsymmetrical toward the red, the second members of the calcium series are symmetrical, while the second members of the strontium series are already unsymmetrical toward the violet.

For convenience of reference I have collected in Table I the lines of the first subordinate "triplet" series of calcium, barium, and strontium.

The chief purpose of the present paper is to point out the importance of determining the pressure-shifts of the first subordinate series of calcium and barium, in which, as we have seen, the character of the lines changes. The interest in these first subordinate series lies in the question whether their lines unsymmetrical toward the violet are, like those of iron, displaced by pressure to the violet, i.e., in the contrary direction to the other lines although belonging to the same series. St. John and Miss Ware, as well as Fabry and Buisson, have shown that the iron lines which widen unsymmetrically toward the violet undergo large displacements to the violet with increased pressure,[1] and Gale and Adams have confirmed this,[2] while those which widen unsymmetrically toward the red undergo large displacements to the red. At present the only evidence available on the point is the difference in the wave-lengths of the calcium arc in air (Holtz[3]) and *in vacuo* (Crew and McCauley[4]). These differences, which are given in Table I, while they should be accepted with some reserve, show that the lines unsymmetrical toward the violet are displaced to the violet by pressure, and the symmetrical lines of the same series, as was found previously by Humphreys, to the red. It has not been doubted until recently[5] that, as discovered by Humphreys, the pressure displacement $\delta\lambda/\lambda$ was constant for all lines belonging to the same series, and this fact has been recommended for the detection of

[1] *Astrophysical Journal*, **36**, 14, 1912; **31**, 111, 1910.

[2] *Ibid.*, **37**, 391, 1913.

[3] *Zeitschrift für wissenschaftliche Photographie*, **12**, 101, 1913.

[4] *Astrophysical Journal*, **39**, 29, 1914.

[5] Swaim, *ibid.*, **40**, 137, 1914.

TABLE I

THE FIRST SUBORDINATE "TRIPLET" SERIES OF CALCIUM, STRONTIUM, AND BARIUM

ORDER IN SERIES	CALCIUM		STRONTIUM	BARIUM
	λ	λ(Arc in Air) −λ(Arc *in Vacuo*)‡	λ	λ
First members.	19916.0	...	...	5819.21 (*ur*)
	19864.6	...	30110.7	5800.48 (*ur*)
	19777.4	...	29225.9	5777.84 (*ur*)
	19507.1	...	27356.2	5536.07 (*ur*)
	19452.9	...	26915.4	5519.37 (*ur*)
	19310.6	...	26024.5	5424.82 (*ur*)
Second members....	4456.81 (s)	+0.011	4971.85 (*uv*)	...
	4456.08 (s)	+ .018	4968.11 (*uv*)	4493.82 (uv)
	4454.97 (s)	+ .016	4962.45 (*uv*)	4489.50 (uv)
	4435.86 (s)	+ .009	4876.23 (*uv*)	4333.04 (*uv*)
	4435.13 (s)	+ .016	4872.66 (*uv*)	4323.15 (uv)
	4425.61	+ .021	4832.23 (*uv*)	4264.45 (*uv*)
Third members.	3645.14*	...	4033.25	...
	3644.86 (*uv*)†	− .003	4032.51 (uv)	4087.53 (u)
	3644.50 (*uv*)†	+ .003	4030.45 (uv)	4084.94 (u)
	3631.10 (*uv*)	− .015	3970.15 (u)	3947.6 (u)
	3630.83 (uv)†	− .010	3969.42	3945.6 (u)
	3624.15 (uv)†	− .001	3940.91 (uv)	...
Fourth members....	3362.42*	...	...	...
	3362.27*	...	...	...
	3361.92 (uv)	− .014	3705.88 (u)	3895.2 (u)
	3350.50*	...	3653.90 (u)	...
	3350.22 (uv)	− .010	3653.32 (u)	3767.5 (u)
	3344.49 (uv)	− .017	3629.15 (u)	...
Fifth members.	...	...	...	...
	3226.26*	...	...	...
	3225.74 (uv)	− .021	3547.92 (u)	3787 (u)
	3215.46*	...	...	...
	3215.15 (uv)	− .019	3499.40 (u)	...
	3209.68 (uv)	− .038	3477.33 (u)	...
Sixth members.	...	...	...	...
	3151.41*	...	...	...
	3150.85 (u)	− .030	3457.70 (u)	...
	3141.29*	...	...	...
	3140.91 (u)	− .062	3411.62 (u)	...
	3136.09 (u)	−0.135	3390.09 (u)	...
Seventh members.....	3101.87 (u)	...	3400.39 (u)	...

(s) denotes symmetrical, (ur) unsymmetrically widened toward the red, (uv) unsymmetrically widened toward the violet, and (u) hazy or diffuse. Those given in italic are new observations; those in roman type are as recorded by other observers.

* Wave-lengths in the arc *in vacuo* by Crew and McCauley reduced to Rowland's scale.

† These lines are given by Saunders as unsymmetrical toward the red, probably by mistake. See footnote on p. 155.

‡ Taken from Crew and McCauley's paper.

series.[1] Judging from the analogy of the iron lines and from the foregoing results for calcium, however, it appears probable that, so far from being constant, the pressure-shift may even be in opposite directions for different lines of the same series.

This brings up the whole question of the relationship between pressure-shift and series. Humphreys found[2] that the pressure-shift ($\delta\lambda/\lambda$) was constant for all the lines of the same series, and that the shifts for the principal, the first and second subordinate series were in the ratio 1:2:4. Although these ratios seem to hold for the majority of cases, about one-third of the total number are exceptions. These exceptions are given in Table II; the mean shifts reduced to λ 4000 at the same pressure for the different series of the same element are quoted from Humphreys' tables. Where data at the same pressure are not available the shift has been calculated from that at a neighboring pressure and is given in parentheses.

TABLE II

EXCEPTIONS TO HUMPHREYS' SERIES LAW

Series	Mean Shift	Ratio	Series	Mean Shift	Ratio
Al {First subordinate.. Second subordinate	50 (40)	1:0.8	Hg {First subordinate... Second subordinate.	70 66	1:0.9
Li {Principal......... First subordinate..	66 (96)	1:1.5	Na {Principal.......... First subordinate*..	73 312	1:4.3
Mg {First subordinate.. Second subordinate	35 45	1:1.3			

* By an unfortunate error or misprint, Humphreys has classed the lines $\lambda\lambda$ 5682, 5688 as belonging to the second subordinate series of sodium instead of to the first, making it appear as though they conformed to his law.

The shifts were reduced to λ 4000 by Humphreys on the assumption that the absolute pressure-shifts are proportional to the wave-length. If the shifts are proportional to some other power of the wave-length than the first, some of these exceptions might be brought into line, but on the other hand new ones would be introduced.

[1] Kayser, *Handbuch der Spectroscopie*, **2**, 327, 579.

[2] *Astrophysical Journal*, **6**, 169, 1897.

Recently Swaim has arrived at entirely different series relationships in studying the pressure-shifts of the zinc lines.[1] He finds that the shifts of the lines in the first subordinate series are *inversely* proportional to the cube of the wave-length, in the second subordinate series *inversely* proportional to the first power of the wave-length, and of non-series lines *directly* proportional to the square of the wave-length. There is therefore no direct relation between the first and second subordinate series.

It seems to me exceedingly probable that all these inconsistencies are due to the existence of a density effect superposed on the true pressure effect. When the arc is placed under pressure there is probably not only an increase in the pressure of the atmosphere surrounding the arc but also an increase in the density of the vapor in the arc owing to a more rapid production of vapor, or other cause. The effect of an increase of density is to displace the unsymmetrical lines in the direction of their greater widening, and by an amount apparently dependent only on the degree of unsymmetrical widening.[2] This might explain Swaim's curious results mentioned above. He noted that the amount of displacement under pressure depended on the diffuseness of the line, and, since the series lines he measured are unsymmetrical toward the red, it seems probable that the large displacements to the red he obtained for the higher and more unsymmetrical members of the series are due, at any rate in part, to increased vapor density.

Many of the anomalous results obtained by Duffield in the arc under pressure are also probably due to density effects. Duffield found that when unsymmetrical lines are reversed the displacement of the reversal falls to half of that of the unreversed line, while the reversals of symmetrical lines remain normally displaced.[3] Now the unsymmetrical lines are those sensitive to density-shift and it would be expected that at the lower density of the absorption line their displacement would be smaller, while symmetrical lines would be unaffected. He also finds that the displacement of a line may have two alternative values at one and

[1] *Astrophysical Journal*, **40**, 137, 1914.

[2] Royds, *Kodaikanal Observatory Bulletin*, No. XL.

[3] *Phil. Trans. Roy. Soc.*, A **208**, 151, 1908.

the same pressure.[1] Duffield says: "Whatever the nature of the disturbing cause, Group III and then Group II [of the iron lines] are most susceptible to it."[2] The lines of Group III, all unsymmetrically widened toward the red, are those most susceptible to density-shift,[3] while the lines of Group II, much widened but not unsymmetrically by pressure, have not been sufficiently investigated. He further says: "On the photographs showing abnormal displacements [approximately twice the normal values], the reversals are more numerous and broader than they are on plates giving normal values";[4] this observation is direct evidence of increased density. I admit, however, that there is no obvious reason why the ratio of the larger displacement to the smaller should be approximately 2:1.

An additional interest for the investigation of the calcium lines under pressure is the question of the behavior of Fowler's series of narrow triplets (λλ 4586, 4581, 4578, etc.). According to Moore[5] the Zeeman effect for these lines is either zero or at least very small, and therefore their pressure displacement would be expected to be small also.[6] It will, however, not be conclusive if they prove to have large displacements in the *arc* under pressure, since these lines are easily displaced by density.[7]

For the elucidation of the relationship between pressure-shift and series, as well as for the solution of solar problems, it seems essential to isolate the pressure effect from the density effect. The means of doing this are not obvious, and the only hope seems to lie in investigating the furnace spectrum under pressure rather than the arc spectrum, for in the furnace the vapor density, dependent on the rate of production and of disappearance of vapor, is almost certainly influenced by pressure to a much less degree than in the arc. All that we know at present is that since the density effect

[1] *Phil. Trans. Roy. Soc.*, A **209**, 216, 1909. [2] *Ibid.*

[3] Royds, *Kodaikanal Observatory Bulletin*, Nos. XXXVIII and XL.

[4] Duffield, *Phil. Trans. Roy. Soc.*, A **208**, 161, 1908.

[5] *Astrophysical Journal*, **33**, 385, 1911.

[6] See King, *Astrophysical Journal*, **31**, 433, 1910; and Humphreys, *ibid.*, **23**, 233, 1906; **26**, 18, 297, 1907; **27**, 194, 1908.

[7] Royds, *Kodaikanal Observatory Bulletin*, No. XL.

is very small for symmetrical lines, their shifts in the arc under pressure are probably due to the pressure only, but that the shifts of unsymmetrical lines are, partly at least, due to density. Evershed suggests to me that the shift to the violet found in the arc under pressure for certain iron lines may be entirely a density effect, and an observation of Humphreys[1] supports this view. It certainly seems probable that many of the laws of pressure-shifts will be modified, and it is hoped simplified, if experiments can be conducted under conditions of constant vapor density. The elimination of density effects in order to obtain true pressure-shifts is one of the most pressing problems for those interested in the displacements in the sun's spectrum.

Kodaikanal Observatory
September 29, 1914

[1] *Astrophysical Journal*, **31**, 459, 1910.

A CRITERION FOR SPECTROSCOPIC BINARIES, WITH AN APPLICATION TO ρ LEONIS

By FRANK SCHLESINGER

It not infrequently happens that an observer of spectroscopic binaries has accumulated a large number of plates of a single star without being able to determine the period or even to decide whether the object is really a binary. This difficulty occurs when the amplitude of the star is small and of the same order as the accidental errors of observation.

The writer has found the following process to be of considerable service in such cases. The method consists in first constructing a frequency-curve for the velocities; this is done by dividing the total range exhibited by the measured velocities into successive groups of equal extent, say 3 km each, and then counting the number of velocities that fall within these groups. Regarding these numbers as ordinates, we plot them and join the ends by a smooth curve, which is the frequency-curve for these velocities. We next compare the shape of this curve with that of the well-known error-curve. If the two are reasonably the same, we conclude that the star is not a spectroscopic binary (within the limits that our measurements are capable of defining), but that the differences in the measured velocities are errors of observation. This conclusion entails the assumption that the orbits of all binaries, whatever their shape and situation may be, will yield frequency-curves for the velocities that differ decidedly from the error-curve. This assumption accords with the facts, for although the frequency-curves differ greatly from each other for various types of orbits, there is no type that corresponds to the error-curve.

If the frequency-curve is such as to indicate that we are not dealing solely with errors of observation but that the object is really a binary, we can in general go somewhat farther and infer something as to the character of the orbit. For this purpose we divide orbits into four classes:

1. *Circular orbits.*—In this case the velocity-curve (that is, the curve that shows the relation between the velocity and the time)

is a sine-curve as drawn in Fig. 1. Let us divide the total range of velocity into ten equal parts as indicated by the horizontal lines. For a large number of observations the frequency with which any

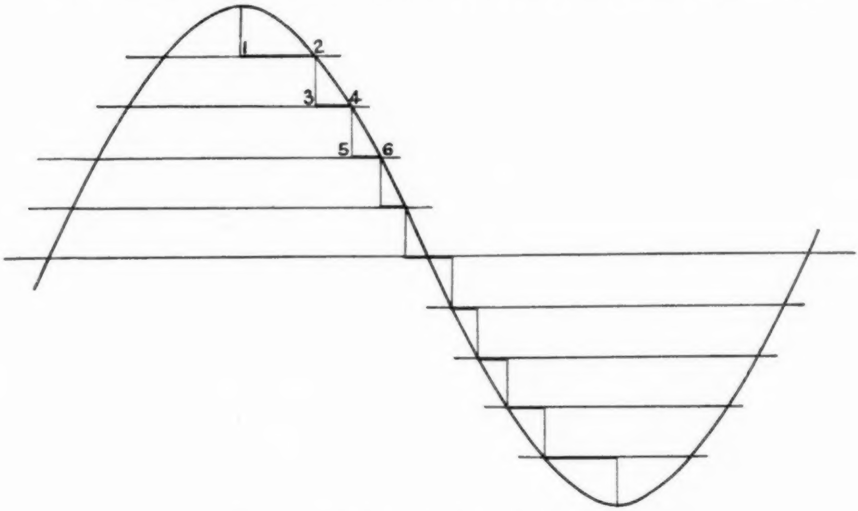


FIG. 1.—Velocity-curve for a circular orbit

velocity occurs will be proportionate to the time-interval during which the velocity is between these successive limits. Consequently the frequencies are proportionate to the lengths (1, 2),

FIG. 2.—Frequency-curve for a circular orbit

(3, 4), (5, 6), etc. The frequency-curve is the full line in Fig. 2. Making allowance for the presence of accidental error, the kind of curve that we should expect in practice is shown by the dotted line.

For a circular orbit, then, high and low velocities occur with the maximum frequency, while intermediate velocities occur more rarely.

2. *Eccentric orbits with periastron near the descending node.*—This velocity-curve is shown in Fig. 3. The frequencies are proportional to the lengths (1, 2), (3, 4), etc., and the frequency-curve therefore has the general appearance shown in Fig. 4. High velocities greatly predominate in number, while low and intermediate velocities are rare.

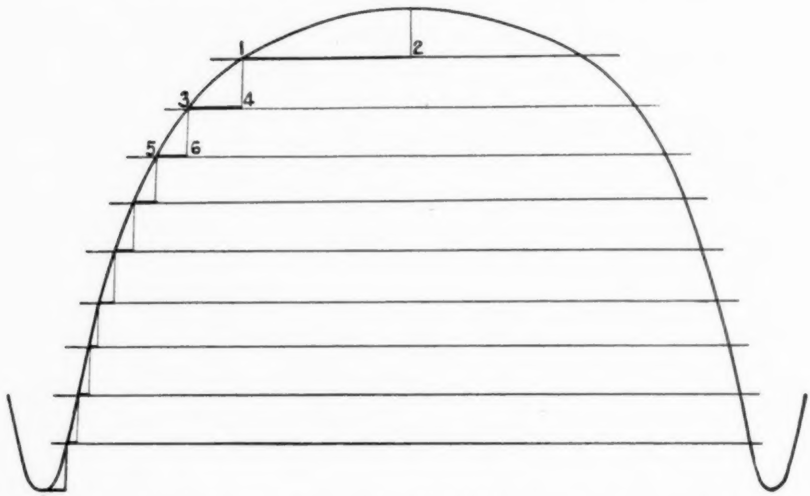


FIG. 3.—Velocity-curve for eccentric orbit with periastron at descending node

3. *Eccentric orbits with periastron near the ascending node.*—The velocity-curve for this case can be obtained by inverting Fig. 3, and the frequency-curve by turning Fig. 4 end for end. Low velocities predominate, while high and intermediate velocities are rare.

4. *Eccentric orbits with periastron removed 90° from the nodes.*—Fig. 5 shows the velocity-curve for the case in which periastron follows the ascending node by 90°, or, expressed in accordance with the usual conventions, the longitude of periastron is 90°. The frequencies are now proportional to (1, 2), (3, 4)+(5, 6), (7, 8)+(9, 0), etc. The corresponding frequency-curve comes out prac-

tically the same as Fig. 2. For the opposite kind of orbit, that in which the longitude of periastron is 270°, the velocity-curve can

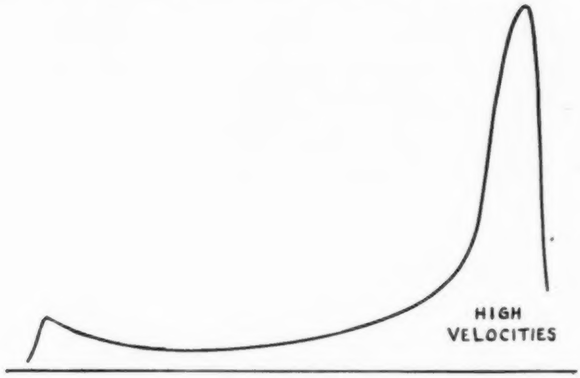


FIG. 4.—Frequency-curve for eccentric orbit with periastron at descending node

be obtained by turning Fig. 5 end for end, but the frequency-curve is precisely the same. The present criterion does not enable us to

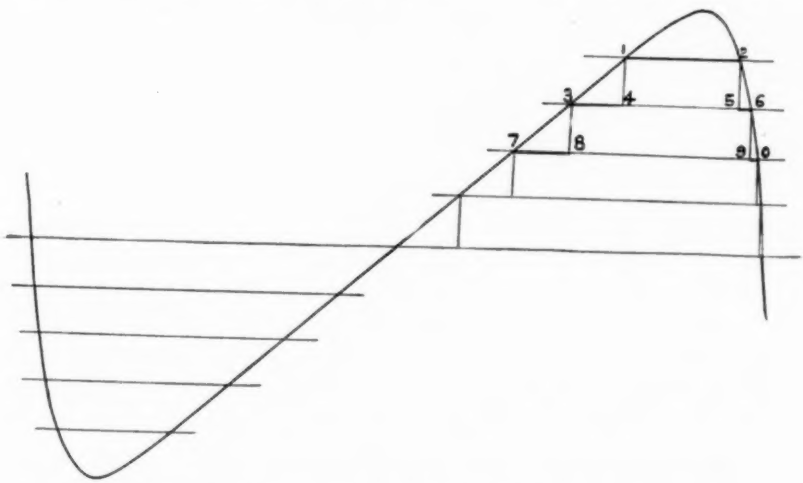


FIG. 5.—Velocity-curve for eccentric orbit with periastron at 90°

distinguish between these two orbits, nor to distinguish either of them from a circular orbit. Consequently if we obtain in any particular case a frequency-curve like that in Fig. 2, we infer either

that the orbit is circular or else that the longitude of periastron is about 90° from the nodes.

The writer has applied this criterion to advantage in a number of cases; the most instructive of these is that presented by ρ Leonis ($10^h 28^m$, $+9°49'$), a helium star of the fourth magnitude. This star was first suspected of varying in its radial velocity by the Lick observers, but later it was removed from their list of spectroscopic binaries. In 1910 and the two following years Mr. Harper obtained sixty-five plates of the star with the single-prism spectrograph of the Ottawa Observatory. From these he was unable to decide whether the object is a spectroscopic binary, though he inclines to believe that it is. Not succeeding in finding a period that will fit the observations, he has (in a very commendable spirit) published[1] his measures and the other data for the plates, in order that they may be available to other astronomers.

The measured velocities for these sixty-five plates range from +26 km to +57 km. Dividing them into groups with 3 km limits, and counting the number of velocities that fall within each group, we have:

3	velocities	less than	+30 km		
1	velocity	between	+30 km	and	+33 km
3	velocities	"	+33	"	+36
6	"	"	+36	"	+39
8	"	"	+39	"	+42
14	"	"	+42	"	+45
20	"	"	+45	"	+48
6	"	"	+48	"	+51
3	"	"	+51	"	+54
1	velocity	between	+54	and	+57

The frequency-curve that these numbers give is very different from the error-curve. The greatest number of velocities is found between 45 km and 48 km; below these limits there are altogether thirty-five velocities, while above them there are only ten. We conclude that the star is a spectroscopic binary, and furthermore, since this is an example of what we have described as Case 2, that the orbit is one of high eccentricity with the longitude of

[1] *Publications of the Dominion Observatory*, 1, 337, 1914.

periastron (always reckoned from the ascending node) in the neighborhood of 180°.

If this conclusion is correct, a search for the period would most profitably concern itself only with the lowest velocities. Computers of the orbits of spectroscopic binaries are only too familiar with the difficulty in deciding upon which branch of the curve certain velocities belong, when they are trying to ascertain the period. In the present instance this additional difficulty is removed for the lowest velocities, because these must all be in approximately the same phase, as the reader may see by referring to Fig. 3.

Acting upon this hint, I examined the seven velocities lower than +33 km and found that with the period 12.28 days all seven of them fall within a day of the phase 7.3 days, the date of Mr. Harper's first plate being taken as the initial epoch. Furthermore, I found that not one of the highest eighteen velocities falls within these same limits. There can therefore be no doubt that 12.28 days is a close approximation to the period of this binary.

An inspection of the velocity-curve obtained by plotting the Ottawa results on this period enables us to estimate that the semi-amplitude of oscillation is 10 km or more, that the eccentricity is probably greater than 0.5, and that the longitude of periastron probably lies between 150° and 210°. Closer approximations to these elements could doubtless be deduced from the present material by a thorough computation, but this work would hardly be repaid. Now that the period of the binary has been established it is possible to secure additional plates near periastron, and these are indispensable for a more accurate determination of the orbit.

In conclusion I may remark that the present criterion is of wider application than the title of this paper implies. For example, we may by its help sometimes infer the character of the variations in the light of a star before the period has been determined. The test is in fact applicable to all periodic phenomena.

Allegheny Observatory
University of Pittsburgh
November 21, 1914

Minor Contributions and Notes

THE SOLAR PROMINENCE OF OCTOBER 19–21, 1914

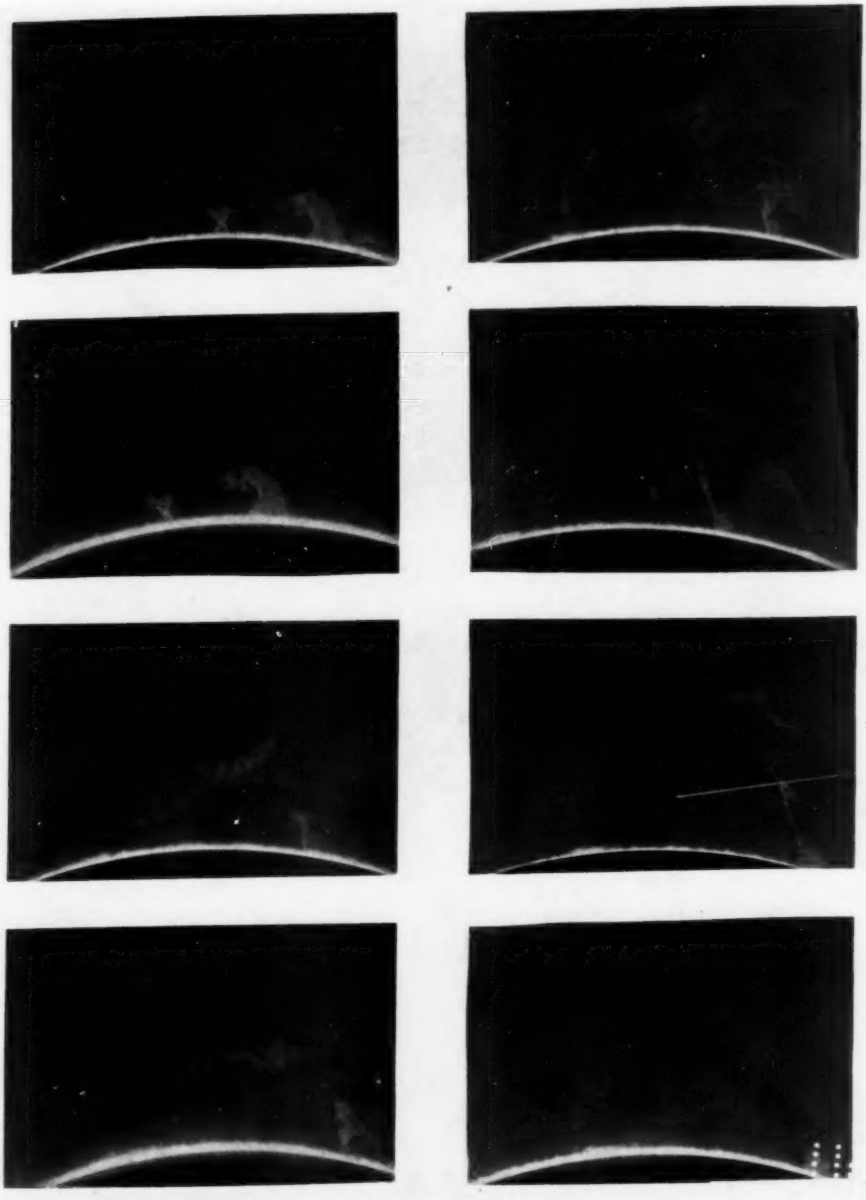
The first observation of this prominence with the Rumford spectroheliograph was made on October 19 at 3^h10^m G.M.T. On account of thin, hazy clouds covering the sky the prominence is only very faintly visible as a pyramid about 120″ high, its base in position angle 239–249°. On October 20 seven photographs, made in the light of the calcium line H, were obtained. Two of these are shown in the accompanying plate. On October 21 thirteen plates of this prominence were obtained between 3^h17^m and 5^h35^m. The last photograph shows the floating cloud at an elevation of 430″ or 308,000 km, but so faintly that no attempt has been made to reproduce it here. A plate exposed at 5^h41^m shows only the low eruptions near the bases of the former prominence and another plate exposed at 7^h19^m shows hardly a trace of activity on this portion of the sun's limb. Although the prominence occurred on the west limb of the sun and its base must have been on the visible hemisphere for at least one of the three days of observation, there is no indication of any eruption shown on spectroheliograms of the disk which were also taken in the H line of calcium.

The change in the character of the prominence from quiescent on October 20 to violently eruptive on October 21 is perhaps its most interesting feature. As a result of the rapidity of the changes and the general faintness of structure, identification of measurable points from one plate to the next is uncertain.

The photographs reproduced in Plate V are reduced about 22 per cent from the originals. The diameter of the sun's image on the scale of the reproductions is 142 mm.

From 5^h40^m to 7^h27^m G.M.T. the low prominence at the extreme right has drifted tangentially to the sun's limb about 50,000 km at a rate of 7.6 km per second. The current 20,000 km higher up is in the other direction, as indicated by the main prominence. If the

PLATE V



a) b) c) d) e) f) g) h)

THE SOLAR PROMINENCE OF OCTOBER 19–21, 1914

a) 20 October 5^h40^m G.M.T.		*e*) 21 October 4^h17^m G.M.T.	
b)	7 27	*f*)	4 49
c) 21 October	3 17	*g*)	4 57
d)	3 56	*h*)	5 07

negatives in the series taken on October 21 be superposed consecutively on that exposed at $3^h 17^m$, using the base of the main eruption as the fiducial point, the cloud forms are seen to retreat radially from a point on the limb of the sun about 100,000 km toward the left from the base. From $3^h 56^m$ to $4^h 17^m$ this motion of the left-hand base of the arch was 7 km per second tangentially. From $4^h 17^m$ to $4^h 49^m$ it was 26 km per second. From $3^h 56^m$ to $4^h 17^m$ the motion of the densest part of the floating cloud away from the limb was 18 km per second. Two condensations are visible at $4^h 17^m$ in the left stem of the arch. They are faintly visible at $4^h 49^m$. Their velocity meantime was 31 km per second in the normal to the limb and 17 km per second in the line joining them with the base of the main eruption. In the same interval the crest flowing toward the right from the main stem had a velocity of 21 km per second. The total area inclosed by the enormous arch shown at $4^h 49^m$ exceeds 145 times the total area of the earth.

20 October	$5^h 40^m$ G.M.T.	21 October	$4^h 17^m$ G.M.T.
	7 27		4 49
21 October	3 17		4 57
	3 56		5 7

Oliver J. Lee

ON THE NON-EXISTENCE OF THE LINE OF WAVE-LENGTH 6708 A IN THE ARC SPECTRUM OF CALCIUM

According to Meisenbach,[1] the line spectrum of calcium contains a line of wave-length 6708.157 A, and this line is also listed as present in the spectrum of calcium in Kayser's *Handbuch der Spectroscopie*.[2] What seems to be the same line, of wave-length 6708.13 A, was found by Hale and Adams[3] to be present in the spectra of sun-spots. For the same line in the spectrum of the sun they give the wave-length as 6708.18. However, while they class this as a calcium line, they state[4] that "it is not certain that this line is due to calcium, as it appears strongly on plates of several other elements." It is well known that a line of the wave-length

[1] *Zeitschrift für wissenschaftliche Photographie*, **6**, 258, 1908.

[2] *Ibid.* [3] *Astrophysical Journal*, **25**, 31, 1907. [4] *Ibid.*

given is the strongest line in the spectrum of lithium, and since in preliminary experiments with ordinary calcium salts it was found that the relative brightness of this line and the calcium line λ 6717.940 varied greatly, it was considered that the supposed presence of the line λ 6708 in the spectrum of calcium might be due entirely to the presence in the calcium salts of lithium in varying amounts as an impurity. This was confirmed by photographing the arc spectrum of gypsum prepared by a diffusion method, when it was found that the line became extremely faint, and not materially brighter than the same line as given by the carbon electrodes themselves. Before use these carbon electrodes had been repeatedly washed in concentrated hydrochloric acid and distilled water, but this was not sufficient to remove all of the lithium originally present in the carbon electrodes. It was found, however, that by allowing the arc to burn for about half an hour before putting in the calcium salt, the lithium could be entirely removed.

When carbon electrodes which did not give a trace of the line λ 6708 were used, it was found that a sample of Kahlbaum's analyzed calcium carbonate gave in the arc no trace of this line, which therefore does not belong in the spectrum of calcium.

This line was then measured in the arc spectrum given by lithium chloride, by comparison with Rowland's value for the calcium line λ 6717.940, and was found to have a wave-length of 6708.040 A. No line near enough to be mistaken for this line appears in Rowland's *Table of the Solar Spectrum Wave-Lengths*. In order to make a better comparison with Rowland's table, the arc was inclosed, and the pressure-shift of the line λ 6708 with respect to λ 6717 was determined from 9 to 167 cm of mercury. The pressure-shift per atmosphere was found to be -0.048 A. Assuming the pressure-shift to be a straight line function, and that the pressure on the sun where such light might be emitted is 5.5 atmospheres, which is according to Fabry and Buisson,[1] it was computed that the wave-length of this line in the solar spectrum, if lithium were present in the sun, would be 6707.782 A. This again is too far from any line given in Rowland's table to be mistaken for it. The nearest lines given in Rowland's table are

[1] *Comptes rendus*, **148**, 688, 1909.

$\lambda\lambda$ 6707.695 and 6708.176. Since this is by far the strongest line in the spectrum of lithium, these results furnish additional evidence that lithium is not present in the sun.

According to Kayser the lithium line λ 6103.77 is of the same brightness as the line λ 6708, but it was found that the commercial calcium chloride used in this laboratory gave no trace of the line λ 6103.77 on plates which showed λ 6708 very distinctly. This shows that the line λ 6708 is a very much more sensitive indicator of lithium than the other.

It was believed by Ramsey that lithium was a decomposition product of copper. Photographs were taken of the arc spectrum of copper using electrolytic copper for electrodes in the first case and bars sawed from samples of Lake Superior native copper, in the second. In the former the lithium line λ 6708 was observed but not in the latter. This is evidence that lithium is a foreign impurity and not a decomposition product.

In conclusion, the writer wishes to thank Dr. H. G. Gale and Dr. W. D. Harkins of this University for their inspiration and assistance in this investigation.

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Reviews

The Reform of the Calendar. By Alexander Philip. London: Kegan Paul, French, Trübner & Co., Ltd. (New York: E. P. Dutton & Co.). 8vo, pp. 127. $1.50 net.

This is a thoroughly sensible presentation of the arguments in favor of the amendment of some of the absurdities of our present calendar. These defects, both direct and indirect, are clearly pointed out, and the leading proposals for reform are given. By excluding New Year's Day from monthly and weekly enumeration, and by evening up the months so that each quarter shall have 91 days, in the order 31, 30, 30, the year would always begin on the same day of the week, and each quarter would similarly have a fixed week day for its commencement. Leap Year would be cared for by having the extra day fall between June 30 and July 1, without being counted as a day of the week, and being known only as "Leap Day." The advantages of a fixed date for Easter, which greatly affects manufacturing interests and the schedules of railways and of all educational institutions, are explained. The Congress of Chambers of Commerce of the world unanimously adopted in London in 1910 resolutions in favor of a fixed international calendar and a fixed date of Easter, which resolutions were reaffirmed by the next Congress held at Boston in 1912.

As modern astronomy touches practical life at none too many points, it might be regarded a duty by astronomers to give their influence in favor of a more rational calendar. The adoption of such a reform could not be better emphasized than by having it go into effect on the first day of the year following the conclusion of peace after the horrible war now devastating Europe.

E. B. F.